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The New "Epoch of Metrology" and the Tenure of Thomas C. Mendenhall in the Coast and Geodetic Survey 1889-1894

Mendenhall Glacier near Juneau, Alaska. named in 1892 for Superintendent Thomas Corwin Mendenhall

Science, Congress, and Grover Cleveland

As the premier scientific agency in the US government, the Coast and Geodetic Survey had never been immune to changing administrations and Congresses and their dictates and budgets. But the tenure of Thomas C. Mendenhall (1889-1894), although productive and largely brilliantly successful, occurred in the middle of the darkest period in the history of the Survey. For the first time in the Survey's history, the leadership of the Survey and their tenure was almost entirely determined by Presidential administration. Grover Cleveland was the Democrat President from 1885 to 1889, Republican Benjamin Harrison was President from 1889 to 1893, and Cleveland returned as President in 1894 to 1897. The dates of those administrations correlate precisely with the disgrace and resignation of Superintendent Julius Hilgard in 1885, Superintendent Frank M. Thorn's tenure from 1885 to 1889, Superintendent Thomas C. Mendenhall's tenure from 1889 to 1894, and the coming nadir of the Survey, Superintendent William Duffield's tenure of 1894 to 1897. To the standard difficulties of the Survey, which included constant struggles with Congressional budgeting and periodic attempts by the Navy to take over the Survey, was added the additional burdens of major changes in senior management in response to the Presidential tide changes.

This Gilded Age, as Mark Twain called it, saw a largely progressive change in federal employees increasingly shielded from politics by the development of Civil Service positions in lieu of patronage appointments by election winners. But these changes occurred mainly at the lower levels of employment in government bureaus. Superintendents and key top staff members now served for specific Presidential tenures. To further complicate matters, much of their productive time and energy was now devoted to managing and/or fending off political appointments to leadership positions, or threats of such appointments. The result was an era of periodic instability at the top, coupled to depressed funding and even declining wages for Survey personnel, as the field expenses monies that had been a de facto supplemental income were reduced or eliminated during the Thorn tenure. Further, as a result of the Hilgard scandal and the Allison Commission, all funding for the agency was under much closer scrutiny by Congressional committees and the auditors of the Department of the Treasury.

On the other hand, the Survey had survived several perilous attempts to dismember it, and the Allison Commission had largely validated its status and significance as the leading scientific agency in the federal government. Further, the Survey was at the forefront in American participation in increasingly internationalized science, which was noted and appreciated by American politicians even when they were entirely ignorant of the science involved. Superintendent Thorn had been brought in as essentially a trusted operative of President Cleveland, and one with broad positive experience in managing government operations. He was the first non-scientist to head the Survey, but he had proved quite successful in rescuing the Survey from the disgrace of Hilgard and his attacker Chenowith. But Thorn, especially, advocated that a proper scientist should succeed him for the good of the Survey.

In 1888, Cleveland ran for re-election for a second term against the Republican candidate Benjamin Harrison. The Republicans were both well organized and corrupt. In New York, Cleveland's own state, they formed an alliance with the New York City and Albany based Tammany Hall to counter Cleveland, the hated Buffalo-based reformer. Although Harrison received 100,000 fewer votes than Cleveland, Harrison controlled the votes in the Electoral College, and Cleveland was defeated.

The new President Harrison appointed William Windon as his Secretary of the Treasury. Windom, a Republican from Minnesota, had served in the House and Senate, and had been Secretary of the Treasury once before, under President Garfield. Harrison and Windom, and no doubt others, decided on a successor to Superintendent Thorn. This took some time. They came into office in March, 1889. The new head of the Survey was announced on July 9th, 1889.

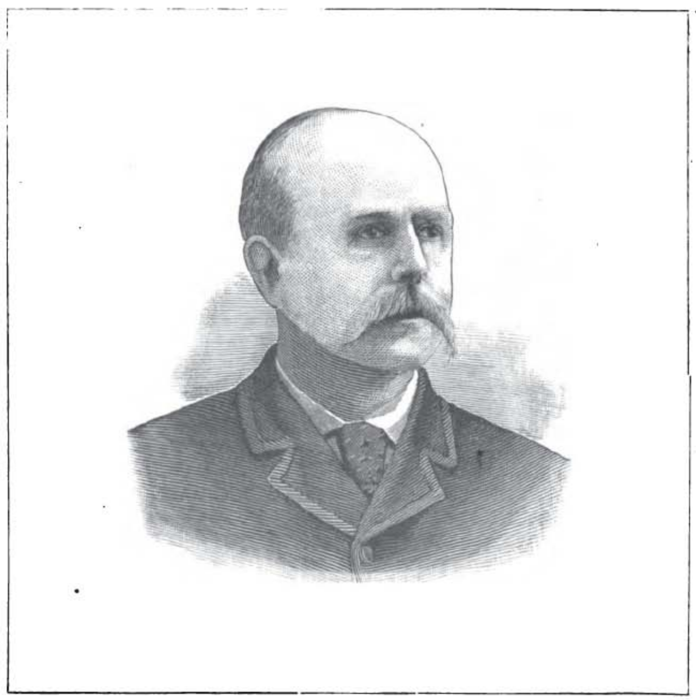
THE

PHRENOLOGICAL JOURNAL

AND

SCIENCE OF HEALTH.

NUMBER 6.] DECEMBER, 1889. [WHOLE NO. 612



THOMAS C. MENDENHALL,
President of the American Association of Science.

Thomas Corwin Mendenhall (1841-1924)

The Soil Underneath Mendenhall's Scientific Tree

Thomas C. Mendenhall had a singular career in American and international science. Hugely productive from an early age, he did pioneering research in a variety of scientific disciplines. Formidably intelligent yet kind and balanced, he played many roles in a long life, and generally rose to leadership positions wherever he went. He was, more than anything else, a master educator, beginning as a village teacher in Ohio. He ended as a learned professor, under that definition of a professor devised by President Gilman of Johns Hopkins University, that a professor was "a student who can also teach".[1]

[1] As cited in Crew, 1925, p. 336.

Mendenhall was born into a Quaker family on a farm near Hanoverton, Ohio, in 1841. Like so many others who ended up in leadership positions in the Survey, he was a fervent Abolitionist. Every year, his family made the pilgrimage to Salem, Ohio, "the western center of the anti-slavery movement" where they would listen to William Lloyd Garrison and Sojourner Truth and other leading lights of the movement. He attended public schools, and also learned independently from books and teachers he found here and there. He ended up in Southwest Normal School, in Lebanon, Ohio. In 1861, he graduated with the degree of *Institutor Normalis*, or Normal Instructor, which was the only degree he ever earned.[2] As a young village schoolteacher in Salem, he celebrated with the rest of this celebrated Ohio community when news came that Lee had surrendered and the war was won. Near the end of his long life, he recalled vivid details of the celebrations that followed. He noted that, for the people of Salem, it was the end of not just four years of war, but also forty years of struggle against slavery.[3]

By 1866, Mendenhall was elected Superintendent of Schools in Butler County, Ohio. In 1868 he became Principal of a school in Columbus, and later that year an instructor of mathematics and science at Columbus High School. There he departed from traditional instruction techniques involving recitation, and instead created a real laboratory. "'Home made' appliances were designed and constructed of lamp chimneys, fruit jars, bonnet wire, and other accessories that one could buy at small cost in the city stores…. From the Western Union telegraph Company he borrowed a discarded 'registering telegraph receiving instrument' which, after being subjected to much labor, would run at a fairly uniform speed. This instrument served as a chronograph for the study of falling bodies and the determination of the frequency of tuning forks, the time element being measured by a seconds pendulum which was perfected to an accuracy of two-hundredths of a second".[4] Mendenhall and his students made experiments in many fields of what would now be called sensory perception and experimental physiology. He also used the rotunda of the state capitol in Columbus to create a Foucault's Pendulum one hundred twenty feet long.

In July, 1870, he married Susan Allen Marple. They were wedded until her death forty-six years later. They had one son, Charles Elwood Mendenhall, who became a physicist.

In 1873, Mendenhall was nominated to be the first instructor of physics and mechanics at the new Ohio Agricultural and Mechanical College. The institution later changed its name, and hence Mendenhall was the first faculty member of Ohio State University. In 1876, for the great centennial celebration of the Fourth of July, he displayed an electric arc light on the top of the state house dome.

Science and Calamity in Tokio

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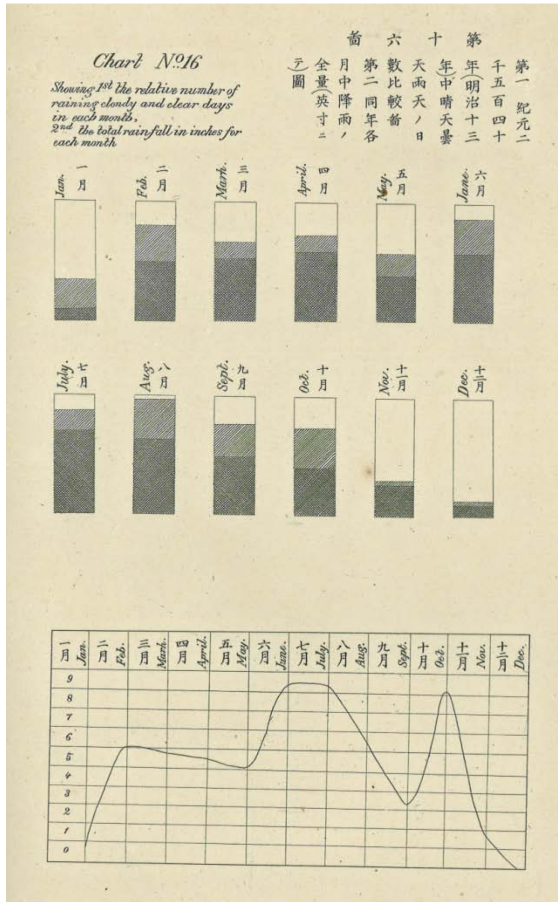
[2] Siebert, 1925, p.2
[3] Mendenhall, 1922, p. 3.
[4] Siebert, p. 5.

In 1878, Mendenhall was nominated to go the new Tokio Daigaku, the Imperial University, in Tokyo (Tokio in Mendenhall's treatise) Japan, as a professor of physics. He and his family lived in Tokyo from 1878 to 1881. As might be expected from his career in Ohio, he engaged in a wide range of research and teaching. One of his new fields of study was meteorology, although even here his interest in sensory perception continued. "Early in the present year a telegraph line connecting the Observatory with the physical laboratory was completed which will without doubt prove to be a great convenience. One of the special considerations which led to its construction was the desirability of taking advantage of the exceptionally favorable conditions for the study of the velocity of sound. At 12 M. of each day a time gun is fired which can be distinctly heard at both the Observatory and the University… It is expected that in this way a large number of observations upon the transmission of sound under widely varying meteorological conditions will in time be secured, which may contribute to the solution of a problem of very considerable importance. Although not a question pertaining strictly to meteorology it is one of great interest and it is hoped that a considerable series of results may be ready for the next general report."[5]

Mendenhall and his students and staff recorded baseline meteorological data from their observatory, and published the results with simple but elegant and effective graphics.

[5] Mendenhall, 1879, pp.41-42.



Monthly totals for rain and raining and cloudy days
For 1879 as measured at the Tokio University Observatory

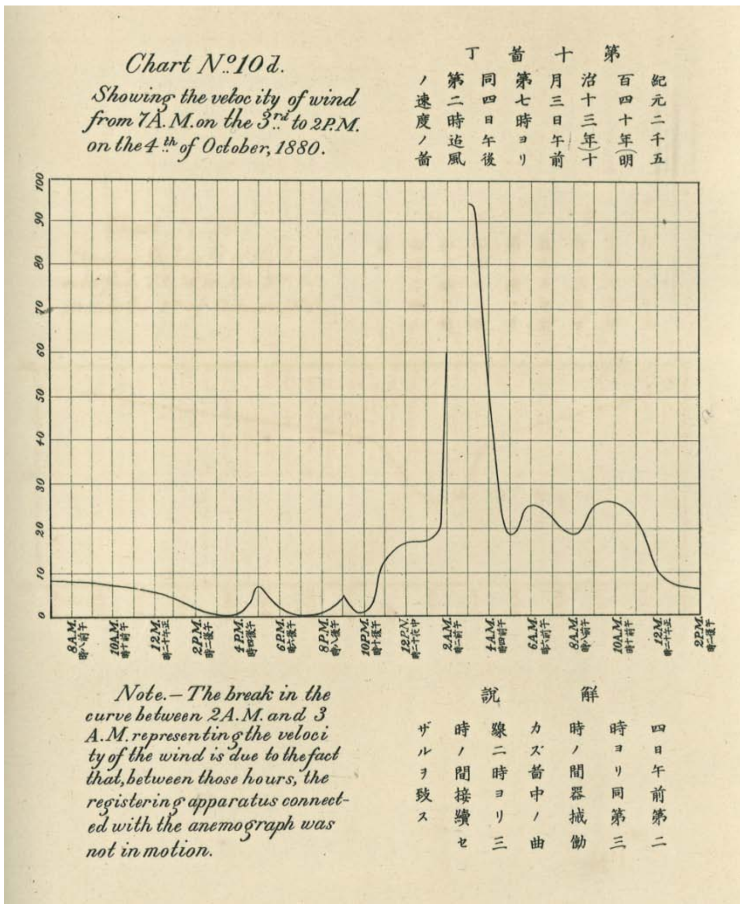
Mendenhall used a set of half second pendulums to measure the force of gravity at Tokyo and also on the summit of nearby Mount Fuji (called Fujinoyama in Mendenhall's treatise). In this, he closely paralleled the earlier work of Charles S. Peirce of the Survey.[6]

Mendenhall, possibly because of his Quaker background, took great notice of calamities and disasters around him in Tokyo, and attempted to apply his theoretical and experimental skills to address them. One arena was that of the frequent and destructive earthquakes of Japan. "There is another phenomenon which, although not strictly meteorological, is of such interest and importance to all residents of Tokyo, and indeed of Japan, as to demand attention and investigation whenever and wherever possible. Much attention has already been given in this country to the study of the phenomenon of earthquakes, and a great variety of seismographs have been constructed and used in their observation. Some of these are very complex… while others are more simple in their construction… While I would not recommend the construction or purchase of any complex registering apparatus for use in the meteorological observatory, I regard it as

[6] Mendenhall, 1881.

highly desirable to erect some simple indicator, which may not be liable to get out of order and which, in connection with some of the time cylinders in use, or to be used in the observatory, may indicate the time of the shock, certainly, or with the smallest of failure. If we shall succeed in this one determination with unfailing, certainly the result will be a contribution of no small value and well worth the trouble and expense which will be rendered necessary."[7]

Another major problem he addressed were the infrequent yet hugely destructive typhoons that swept over the city. One specific storm struck the city on October 4th, 1880. Mendenhall studied it in detail.



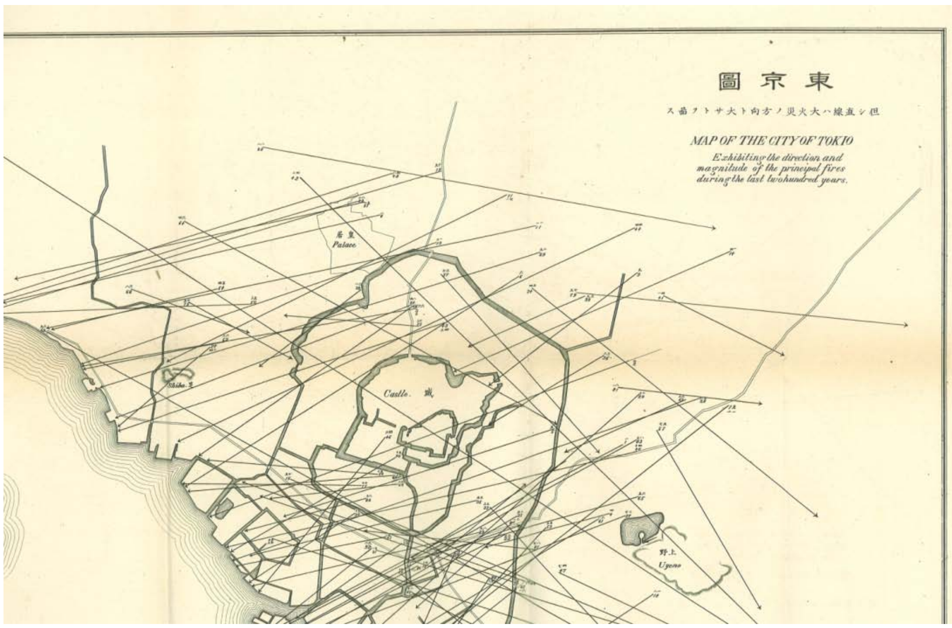
Wind velocities on Oct. 4, 1880 as measured at the Observatory

Characteristically, Mendenhall mused that it would be possible to develop a storm warning system for the public good. "In conclusion, it may safely be said, especially in view of the damage done to buildings, shipping, etc. that this was one of the most violent storms experienced here for many years. From facts already known concerning other points along the coast of Japan, it would seem that, had an efficient system of

[7] Mendenhall, 1879, p. 42.

observations, telegrams, and signals existed, timely warning might have been given of its approach and, possibly, much property and many lives saved."[8]

Mendenhall's final research arena was that of fires in Tokyo. The city was famously constructed of wood and paper, and densely populated, and when fires occurred, especially under high wind conditions, the resulting damage could be enormous. With Professor K. Yamagawa, Mendenhall prepared an analysis of Tokyo fire behavior for the previous 200 years.



Detail from Fire Direction and Damage Scale for the last 200 Years
In Tokio, prepared 1880

In 1881, Mendenhall and his family returned to what was now Ohio State University. Following the trajectory established in Tokyo, he was now becoming a specialist in the physics of meteorology. He also spent more time as a lecturer in science, which brought him to attention outside of Ohio. "The lecture season at the Lowell Institute in Boston is drawing to a close…This year an unusual variety has been offered, and the audiences have been large and attentive… These series were followed by a course of six lectures on Motion and Matter by Professor Thomas C. Mendenhall of the Ohio State University, beginning Dec. 4."[9]

Mendenhall comes to Washington and the Signals Service

And thus, in 1884, he was called to Washington to his first stint as a federal scientist. He served two years as a Professor of Electrical Science in the U.S. Signal Service, the predecessor of the Weather Bureau and the National Weather Service.

[8] Mendenhall, 1880, p. 27.
[9] Science, 1883, p. 236.

Signal Service Headquarters, 1880
From Frank Leslie's Illustrated Newspaper

At the Signal Service Mendenhall was introduced to the practice of science in the federal government, and also in a sense to the Coast and Geodetic Survey. The chief scientist of the Signal Service was Cleveland Abbe, assisted by William Ferrel, both of whom had been employed in the Coast Survey at earlier stages of their careers. Near the end of his long and active life, Mendenhall returned to those years in the Signal Service, as a part of the memoir written after the death of Cleveland Abbe. Mendenhall wrote a uniquely detailed and reflective account of Abbe and the Signal Service and its science and its awkward place in the US Army which is worth examining, in part for the perspective it gives on his subsequent return to Washington to lead the Coast and Geodetic Survey.

> "Although the years of my acquaintance with Professor Abbe were nearly fifty in all, my intimate association with him began about a third of a century ago. It was in the 'early eighties' of the last century when the Weather Bureau was the Signal Corps of the Army or the Signal Corps was the Weather Bureau, both modes of stating the relation of the two being essentially correct, as for many years the operations of the Signal Corps were practically restricted to its activities as a weather forecasting service. In order to understand and appreciate the almost unique combination of qualities, moral and intellectual, which enabled Abbe to play his great part in the creation and development of what is in many respects the most important of the scientific bureaus of the Government, it is necessary to know something of the conditions under which he worked during the earlier stages of that development.

"At thirty years of age, as the enthusiastic director of the Cincinnati Observatory, he had successfully inaugurated a system of weather reports by telegraph from which daily forecasts were attempted. His success led to an act of Congress providing for the utilization of the Signal Corps of the army for the organization of a general weather service, and Professor Abbe was called to Washington as meteorologist in that service. At that time he was the only man in the country having experience in or knowledge of weather forecasting for the use of the public based upon the principles of scientific meteorology, and for some time the duty of daily interpreting the meteorological observations made in all parts of the country devolved upon him alone. The new service was immediately popular, and though barely thirty years of age, he soon became generally known as 'Old Probabilities,' or 'Old Prob.' Realizing that the then state of our knowledge of meteorology was quite inadequate for anything like accurate forecasting, he sought to induce the War Department to obtain an annual appropriation for the purpose of maintaining a systematic study of the subject, both theoretical and experimental. Methods of transacting business assumed to be necessary in a military organization in time of peace are decidedly inimical to scientific investigation and research, and from the start Abbe's plans met with obstruction at almost every turn, not always due to unfriendliness-indeed more often to mere inertia of the system. In overcoming this opposition, which at times was so unyielding as to completely discourage all others who were interested, he was successful, because of his two most characteristic traits were an inexhaustible enthusiasm for the work, which amounted almost to an obsession, and an equally inexhaustible patience in meeting unfriendly or unintelligent criticism.

"I think not much was actually accomplished until Gen. W.B. Hazen became Chief Signal Officer in 1880. For the two great advances made during the first few years of his administration credit belongs to Abbe, almost if not quite alone. Certainly the initiative and general plans were his, though, of course, there could have been no success without the friendly support of the chief Signal Officer. Perhaps the most important of the two was the improvement of the character of members of the corps by means of a provision for special enlistment of young men, mostly college graduates, with the rank of sergeant in the Signal Corps, with exemption from most of the ordinary duties of the regularly enlisted soldier.

"The other was the establishment of what was known as the 'Study Room,' in which all meteorological problems arising in the service were subjects of investigation by civilians employed for the purpose, two or three of whom had the rank or title of 'Professor' and some others that of 'Assistant Professor,' and arrangement probably suggested by the practice of the military and naval academies. This was shortly supplemented by the establishment of a laboratory for experimental investigation, the inauguration of which I undertook at the earnest solicitation of Professor Abbe in 1884.

"The study room and the laboratory formed, also, a sort of school for the enlisted men, to whom courses of lectures on meteorological, physical, and allied topics were given. The distinguished meteorologist, William Ferrel, was one of the professors, and in addition to a part in the instructional work his assignment embraced a theoretical investigation of the general principles of meteorology with a view to the improvement of the work of forecasting the weather. The vitalization of the service through these important changes resulted, happily, in the acquisition of such young men as Marvin, Fassig, McAdie, Morrill, McRae, Russell, and a number of others, some of whom are still in the service, and from several of whom have come in later years contributions to the science of meteorology of very great value.

"The difficulty of doing scientific work, either theoretical or experimental, under conditions, then existing, can be appreciated only by those who have attempted it, and it is because of Professor Abbe's extraordinary courage and success in meeting these difficulties that I am referring to them at such length. There was at that time a sort of tradition among military men-which may not yet be extinct-implying that a properly signed written order from a superior officer to do a certain thing carried with it not only the duty of doing it, but also the capacity to do it, which I imagine may be a rather stimulating idea for one engaged in battle, though of doubtful value in scientific research.
"Our duties were assigned to us in regular instructions or 'orders' from the chief Signal Officer, written on regulation order slips on which our initials were placed, as evidence that we had received and understood our instructions.

The North Side Offices of the Signal Corps, G St. Washington, DC

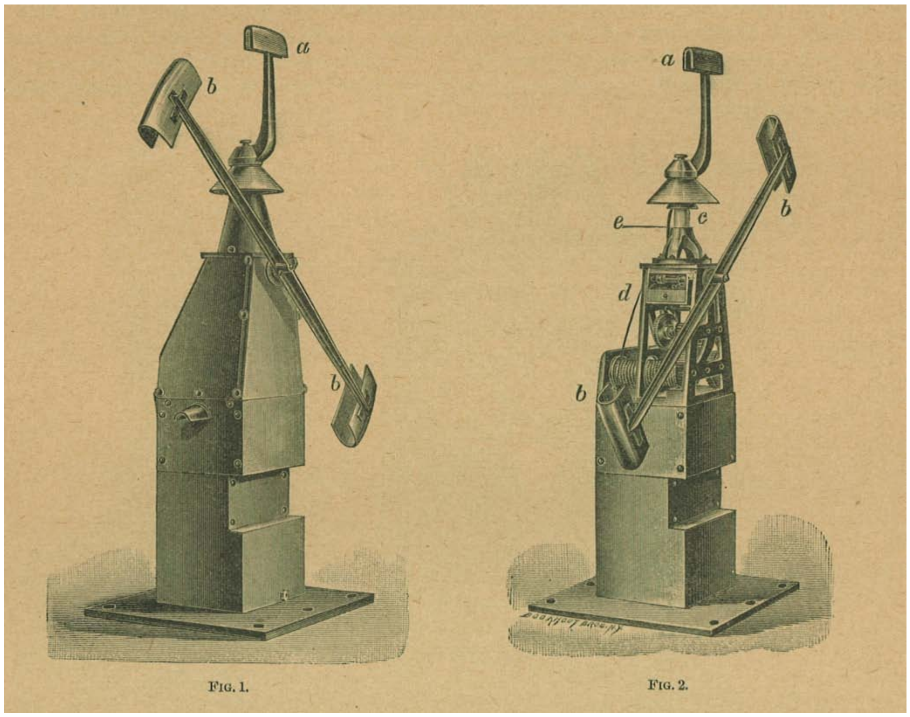
"The headquarters of the Signal Corps were at that time on 'G Street,' near the War Department, and by a curious chance the two somewhat conflicting elements were housed on opposite sides of the street, the study room, the laboratory, the instrument testing division, etc., being in one building on the south side, while the offices of the Chief Signal Officer and his military aides, the property and disbursing officer, the forecasting officers, etc., were on the north. That controversies between the two were on the whole rather infrequent and rarely acute was due, more than to anything else, to Abbe's unfailing good nature and general willingness to be the subject of the obloquy of both sides.

"The military tradition I have referred to above did not harmonize with the traditions and practice of scientific research. The most industrious and enthusiastic investigator would be somewhat dismayed by the receipt of 'instructions'-not much unlike the following: "you will begin on Monday next an investigation of the cause or causes of the attraction of gravitation, and make a preliminary report upon your work in two weeks. A final report is to be ready by the first of next month.' Unfortunately Nature does not yield her secrets in response to orders, and there were naturally many failures to 'get results' on time."[10]

Atmospheric Electricity

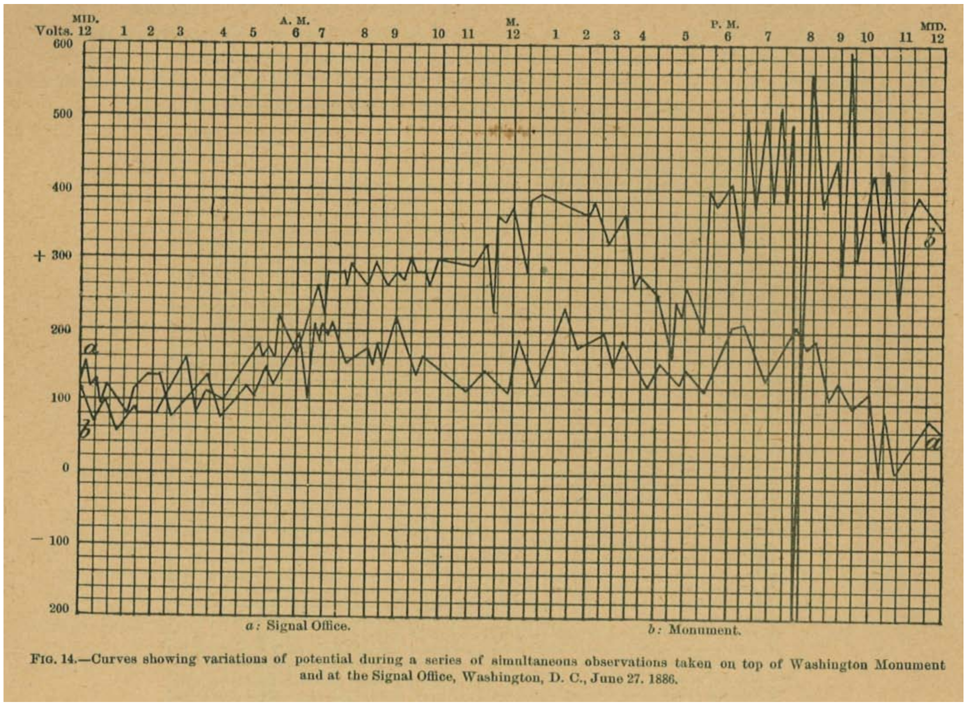
[10] Mendenhall in Humphreys, 1919, 479-481.

Mendenhall's major research project was the study of atmospheric electricity and its relationship to storms and storm systems. His major instrument was his modification of the water dropping collector device originally designed by William Thompson (later Lord Kelvin). Photographic exposures of the behavior of water droplets as influenced by atmospheric electrical potential allowed the changes in electric potential in the air to be detected at the site of the instrument.



Mendenhall's Modified Water Dropping Collector
Seen with housing and with housing removed

Mendenhall created a small network of collectors, their data and timing linked by the telegraph network that was at the heart of the Signal Service. As Mendenhall noted, the great distances between his collectors made it impossible to use them to examine any specific storm system collectively. Only in one instance, when he had two collectors, one mounted at the Signal Service headquarters, the other mounted in the observation room at the top of the Washington Monument, was he able to acquire one data set on the remarkable differences in electric potential at the ground and at elevation, as a summer thunderstorm moved over Washington.



Variations in Electric Potential, June 27, 1886
Between the Signal Service office and the top of the Washington Monument
The great potential spike occurred as a lightning storm crossed over the Monument

On August 31, 1886, the great Charleston earthquake struck the coastal areas and piedmont of South Carolina. Mendenhall was sent to the scene to describe and analyze the earthquake. His report on what he encountered, published in the Monthly Weather Review, includes some observations that harken back to his time in Tokyo, and his speculation about seismic networks and linkages between observers. “The table below contains a resume of information received at the office of the Chief Signal Officer from regular observers of the Service and from a number of voluntary observers. The time, place, supposed direction, duration, and estimated intensity are given. Much discrepancy will be observed in the records of time…A study of this column will show the great importance, in making such observations, of determining the error of the clock or watch at the earliest possible moment by comparison with the time of some known meridian. It must be said, however, that the extended use of standard time has rendered these results vastly more accurate than they otherwise would have been. Telegraphic time signals are now within the reach of most people, and during the last two or three years a great improvement in the accuracy of time-keeping among the people has taken place.”[11]

The Increasingly Public Mendenhall

Mendenhall’s first tenure in Washington ended when he was elected President of the Rose Polytechnic Institute in Terre Haute, Indiana. His return to teaching led to an elegantly written general history of the development of electrical science called *A*

[11] Mendenhall, 1886, p. 234.

Century of Electricity.[12] He begins the volume: "Within these hundred years there have been three notable discoveries in electricity, around which all others cluster, and from which they have all grown. These three have immortalized the names of Galvani and Volta, Oersted and Ampère, and Faraday."[13] Mendenhall would in turn "re-immortalize" these foundational scientists by giving their names to the definitions of the fundamental electrical units.

Method of drawing electricity from the clouds suggested by **Franklin.** Enlarged from cut accompanying his original paper.

From Mendenhall's *A Century of Electricity*

Finally, Mendenhall was elected to increasingly higher positions in the infrastructure of science in the United States. By 1882, upon his return from Japan, he was elected Vice President of Section B (Physics) of the Association for the Advancement of Science. He gave a concluding address at the end of his term which sounded a theme which resonated throughout his career, and one that is fundamental to understanding his tenure as Superintendent of the Survey. He noted:

> "We are mistaken if we suppose that science is advanced only through contributions which are the results of original research in our laboratories and libraries. Even if so narrow a view be taken, it will be admitted that the talent for research is fostered and encouraged, if not,

[12] Mendenhall, 1888.
[13] Ibid., p. 221.

> indeed, created by an atmosphere of recognition and appreciation. The existence of such an atmosphere is in itself a blessing and its production is certainly worthy of our highest efforts. To this end it is desirable and necessary to bring about a more general diffusion of accurate knowledge concerning the elementary principles and propositions of the science of physics, as well as some degree of familiarity with the methods of physical investigation. I do not refer, of course, to the demands or the necessities of those who expect to undergo a course of training for the purpose of becoming themselves physicists; but rather to the diffusion of this knowledge among the masses of the educated people in general. That this diffusion is not taking place to any great extent and will not, according to natural laws alone, is patent to any observing physicist, who cannot fail to have come in contact with prevailing and pernicious errors, which often carry the weight of repetition, and now and then of recognized authority. I am aware that this is not an association of educators, and that pedagogics is not, as yet, one of the sciences specifically indicated as worthy of advancement at our hands; but if the growth of a tree is to be made healthy and permanent it is not safe to neglect the soil into which its roots penetrate. Train it and prune it as you will, to grow into vigor and strength, it must spring from a generous earth which, though beneath it and below it, must be in harmony with it in order to supply the proper and necessary materials for its sustenance."[14]

Mendenhall's summation as Vice president of the AAAS section marks an apex in his Quakerish optimism about nurturing the soil from which the scientific tree will flourish. After his first round of federal science in the Signal Service, and at the end of his tenure as President of the AAAS, he sounded a more nuanced and troubled theme, reflecting what he had learned in the years since. His reflections would prove a prescient foreboding for his future second career in federal science:

> "It is generally recognized that, aside from all questions of a particular political nature, this country is to-day confronted by several problems of the utmost importance to its welfare, to the proper solution of which the highest intellectual powers of the nation should be given. The computation of the trajectory of a planet is a far easier task than forecasting the true policy of a great republic, but those qualities of a human intellect which have made the first possible should not be allowed to remain idle while an intelligent public is striving to attain the last. That men of science have not, thus far, made their full contribution to the solution of some of these great problems is due to the fact that many have exhibited an inexcusable apathy towards everything related to the public welfare, while others have not approached the subject with that breadth of preparation in the close study of human affairs which is necessary to

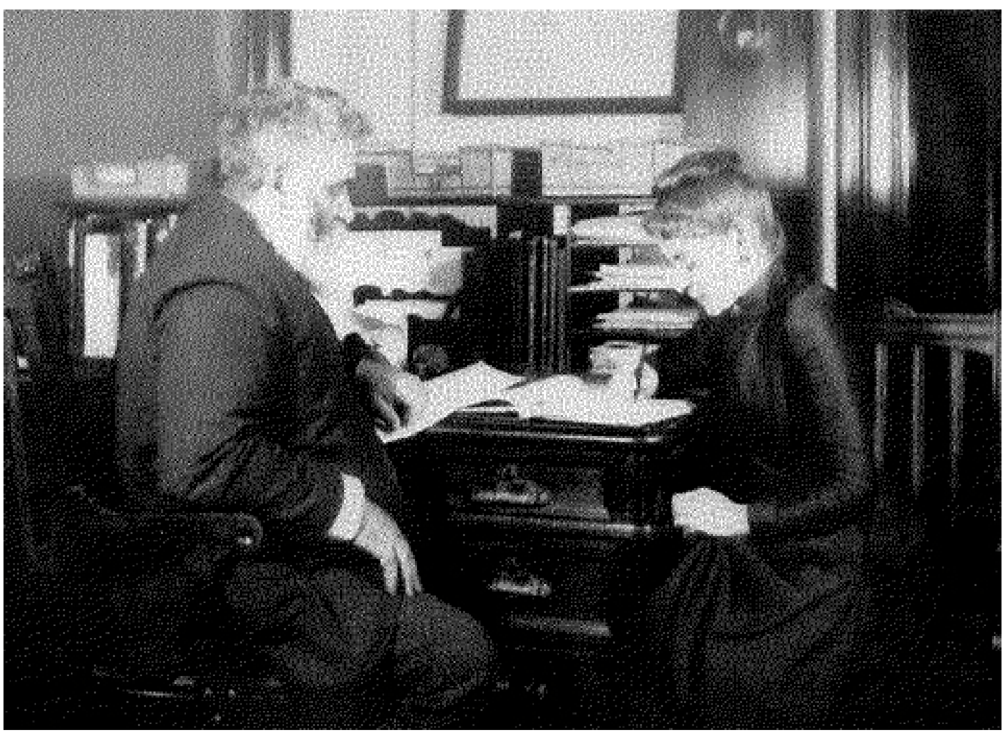
[14] Mendenhall, 1882, p. 5.

establish the authenticity of their equations of condition. As already intimated, we do not seem to be getting on in this direction."[15]

The Coast and Geodetic Survey as Mendenhall found it

The Survey had survived many crises when Mendenhall arrived, but its stability was fragile. The shift in the White House from Cleveland to Harrison had ended—or actually just postponed—certain threats to the agency, but the see-sawing balances of power between the Democrats and Republicans in both the House and the Senate kept the agency's budget uncertain, and additional threats to turn the Survey over to the Navy were likely, as they had been for decades. Mendenhall, to be effective, would have to work fast. For the first years of his tenure, he was quite successful, but then the Survey's fortunes turned.

The effective leader of the Survey was Benjamin Colonna, who had proved critical to Thorn's tenure because Thorn knew neither the agency or its science. Mendenhall, although not a geodesist, had become a proficient scientist and learned quickly. So Mendenhall and Colonna continued in a partnership in managing the agency. Colonna also forged another partnership.



Benjamin Colonna and Fannie Bailey at Survey headquarters
Undated photograph from B. Colonna's biography by Judith Scharle

[15] Mendenhall, 1890, p. 12-13.

Fannie Bailey had worked as a secretary to Colonna since 1885. When she was absent with a family emergency for several weeks, Colonna realized how much he missed her, and that he was in love. He proposed, and in 1890 they wed in Washington. Their marriage was successful, and was also possibly the only documented relationship between any personnel in the Coast and Geodetic Survey.

Mendenhall's tenure was short enough that perhaps the best way to summarize the Survey in his tenure is to divide the coverage between Survey work that was the continuation or accomplishment of previous efforts presented first, followed by activities that began under his tenure, or that displayed his particular stamp.

Major Circles Closing and Projects Completed

In 1881, Congress had ended the division of the District of Columbia between the City of Washington and the County of Washington. From that point on, the entire District was to be administered as a unit. The Army Corps of Engineers had mapped the City several times. With the unification of the District, the former county lands and developments remained to be mapped. The Survey was given the task. It took almost a decade, reflecting the detailed scale of the mapping (1:10,000 scale), the densely rugged terrain and the thickets of vegetation that had regrown after the denudation of the Civil War, and the fact that mapping work in the District was often reserved for what would have been the office season for topographers working on isolated coasts. Under Mendenhall, the last of the maps of the District were completed.[16]

[16] See Baker, 1894 for a thorough summary of the Survey's mapping project in the context of cartography of the District in the 19th century.

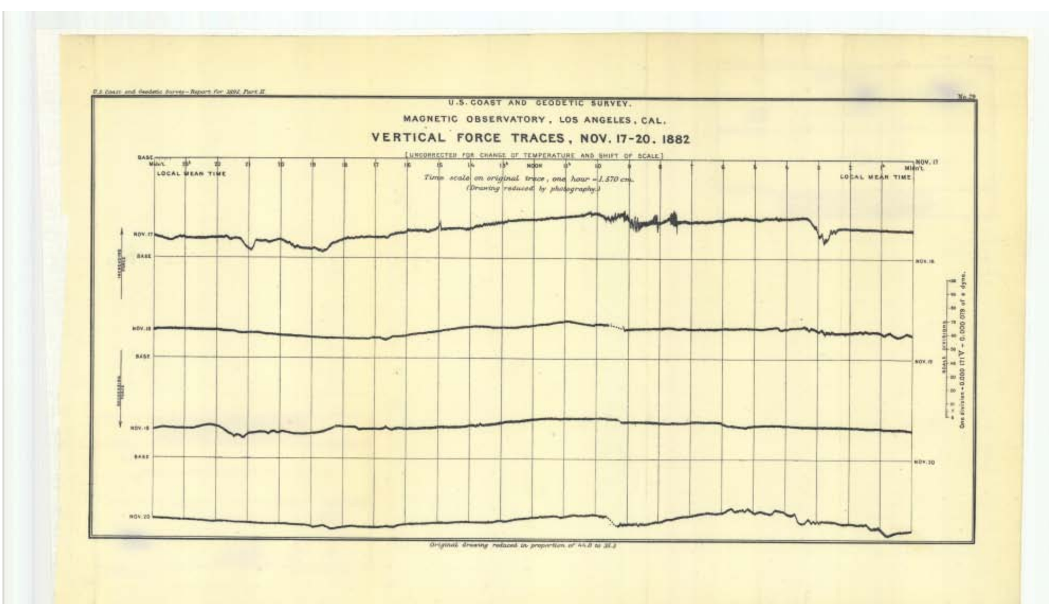
District of Columbia Sheet No. 34, 1892 The unmapped lower right-hand corner is the former City of Washington, the mapped area part of the former County

From 1882 to 1889, the Survey had maintained a magnetic observatory in Los Angeles, California, the first long-range outpost of magnetic research outside the east coast. The key instrument used was an Adie recording magnetograph that A.D. Bache has purchased during the Civil War.

FIG. 5. Adie magnetograph as operated at Los Angeles, California, later at San Antonio, Texas, and now at Cheltenham, Maryland.

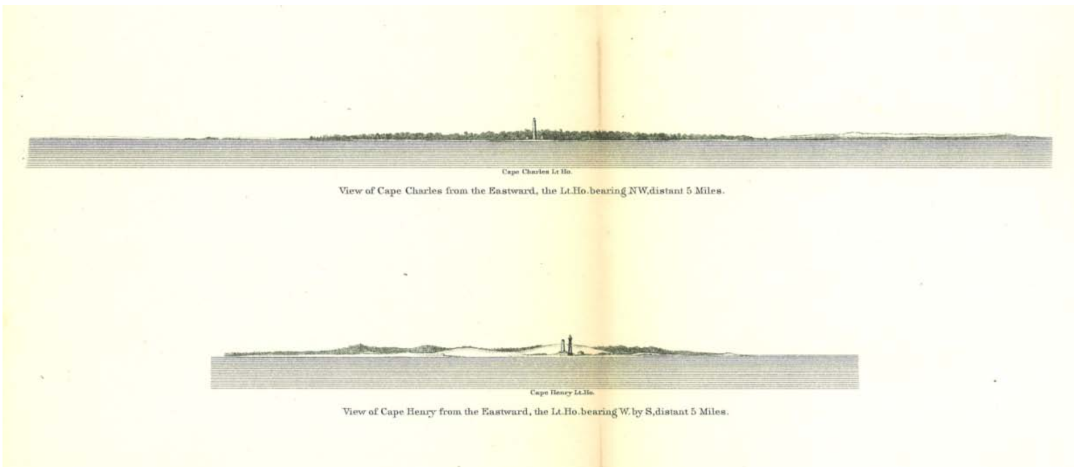
Adie magnetograph

The Los Angeles observatory was moved and re-assembled in San Antonio, Texas. For the next three years, Charles A. Schott analyzed the Los Angeles data, and published descriptions and analysis of the data in the annual reports.



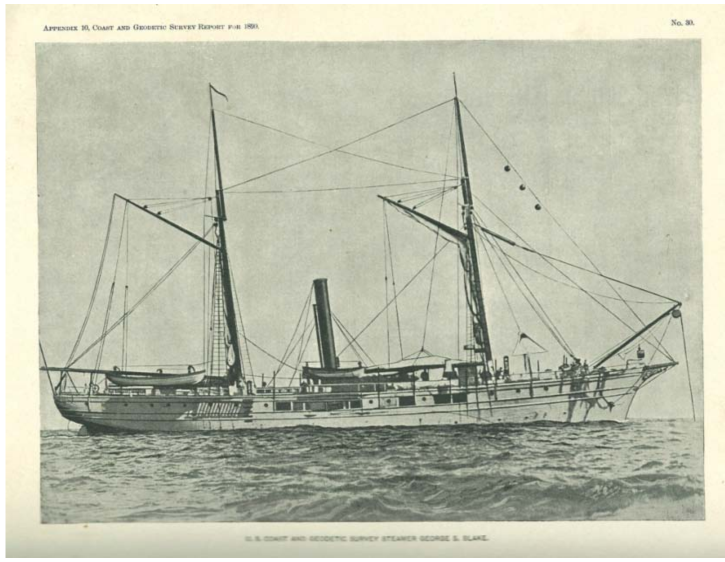
Vertical Forces Traces of the Great Magnetic Disturbance,
November 17-20, 1882. Figure No. 22, 1892

In the 1870s, the Atlantic Local Coast Pilot series had been published, a culmination of the project initiated in 1867 when the Survey acquired the Coast Pilot franchise from the Blunt family. A decade later, there had been so many changes to ports and navigation along the Atlantic coast that a major revision was necessary. The original series was called "local" because the 22 volumes each covered only small areas of the coast. The revised and republished series, now called the Atlantic Coast Pilots, consolidated the material into seven parts published in six separate volumes. For whatever reason, there had never been a Local Coast Pilot volume for Chesapeake Bay. The new series included Chesapeake Bay, and utilized the coastal views originally drawn by John Barker in the 1870s, but never before published.



Views of Cape Henry and Cape Charles, at the mouth of Chesapeake Bay,
By John Barker, 1891

The Survey's major research in deeper water hydrography and the structure and currents of ocean basins really began in 1874 with the launching of the steamer George S. Blake, which, along with its "sister' ship the Albatross of the US Fish Commission, were the great American oceanographic research vessels of the 19th century. Lt. Commander John Elliott Pillsbury perfected deep ocean anchoring, which, in conjunction with newly designed current meters and other instruments, allowed the three-dimensional structure of the Gulf Stream to be investigated.



The Steamer *George S. Blake* 1874-1905

These culminated in 1890 and 1891 with Pillsbury's publication *The Gulf Stream*, considered to be among the best series of oceanographic observations from its century. Pillsbury was a forceful writer, and his text is a classic in its conveying some sense of the enormous powers of the ocean:

> "Man stands with bowed head in the presence of nature's visible grandeurs, such as towering mountains, precipices, or icebergs, forests of immense trees, grand rivers, or waterfalls. He realizes the force of waves that can sweep away light-houses or toss an ocean steamer about like a cork. In a vessel floating on the Gulf Stream one sees nothing of the current and knows nothing but what experience tells him; but to be anchored in its depths far out of the sight of land, and to see the mighty torrent rushing past at a speed of miles per hour, day after day and day after day, one begins to think that all the wonders of the earth combined can not equal this one river in the ocean."[17]

New Frontiers under Mendenhall

The Coast Survey as such really stabilized and took its form under A. D. Bache. Perhaps nothing was as constant in the Survey than the massive folio volumes of the annual reports that Bache had initiated. These were, in effect, a scientific journal that published one issue a year. There were advantages to that, but also disadvantages, which became increasingly apparent as the scientific status and reach of the Survey expanded. Under Thorn the Survey had begun to publish Bulletins, which were essentially specific scientific appendices published by themselves. Mendenhall himself wrote one of the most important of them, which will be discussed in the final section of this chapter,

[17] Pillsbury, 1890, p. 462

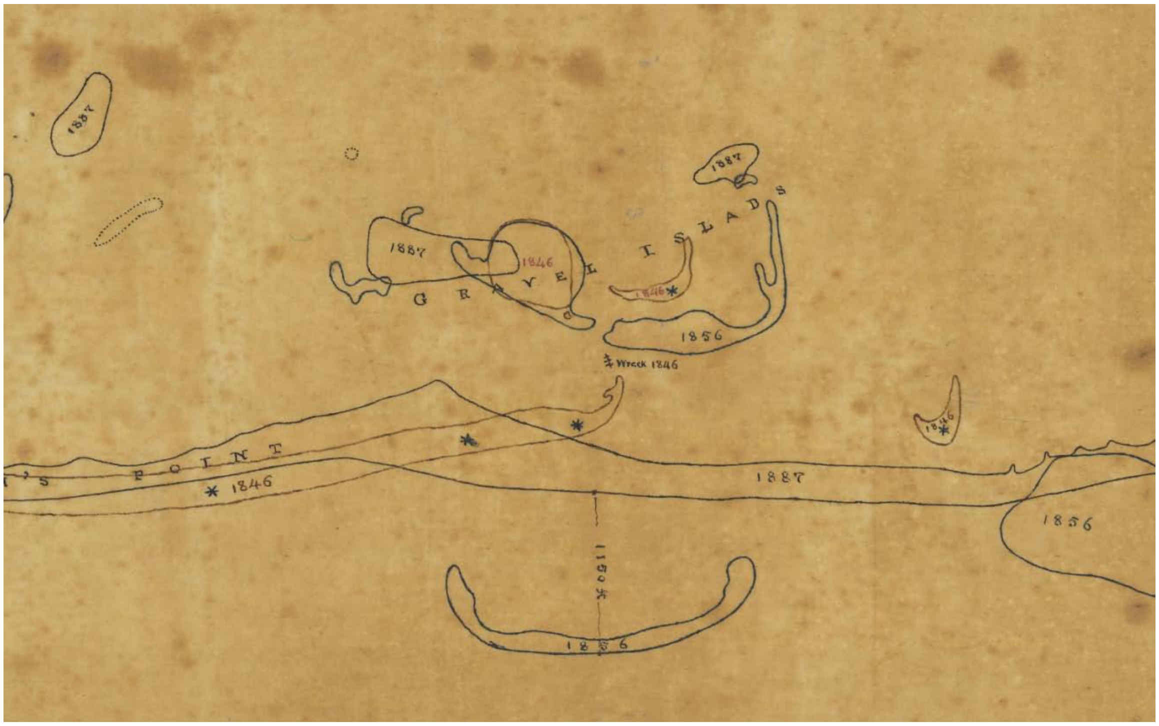
featuring the Coast and Geodetic Survey at the World's Columbian Exposition of 1893, which was in many ways Mendenhall's finale with the Survey.

Mendenhall continued the Bulletins, but reduced their size from quarto (8½ by 11 inches) to octavo (5 ½ by 8 inches) to make their distribution easier. He also divided the annual reports into two sections: Part I, the historical section, represented the reports of progress form the various divisions in the various sections, while Part II, reduced to octavo size, included "the professional papers related to the methods, discussions, and results of the Survey which have been approved for publication during the year. Such illustrations as are needed accompany them….In the future distribution of the Report, Part II only will be sent, as it is believed that this will include all that is generally desired, and in a much more compact and convenient form than that of the old quarto".[18] It should be noted that this division for the annual reports into two sections was discontinued once Mendenhall resigned.

The Survey continued its usual series of harbor charts, nautical charts, and sailing directions, updating them as they could, given the dueling tensions of lowered budgets and fewer personnel versus rapid changes in the American coasts and maritime transport systems, which required updating charts and mapping new harbors. In this, the Survey was a major participant in the very processes that were changing the coasts. This can be seen in the introduction to Henry Marindin's 1892 appendix no. 8, "On the changes in the ocean shore lines of Nantucket Island, from a comparison of surveys made in the years 1846 to 1887 and in 1891". Here Marindin is embracing the full span of the modern Survey under Bache, through the decades of research by his mentor Henry Mitchell, to his own work as Mitchell's successor as the Chief of Physical Hydrography.

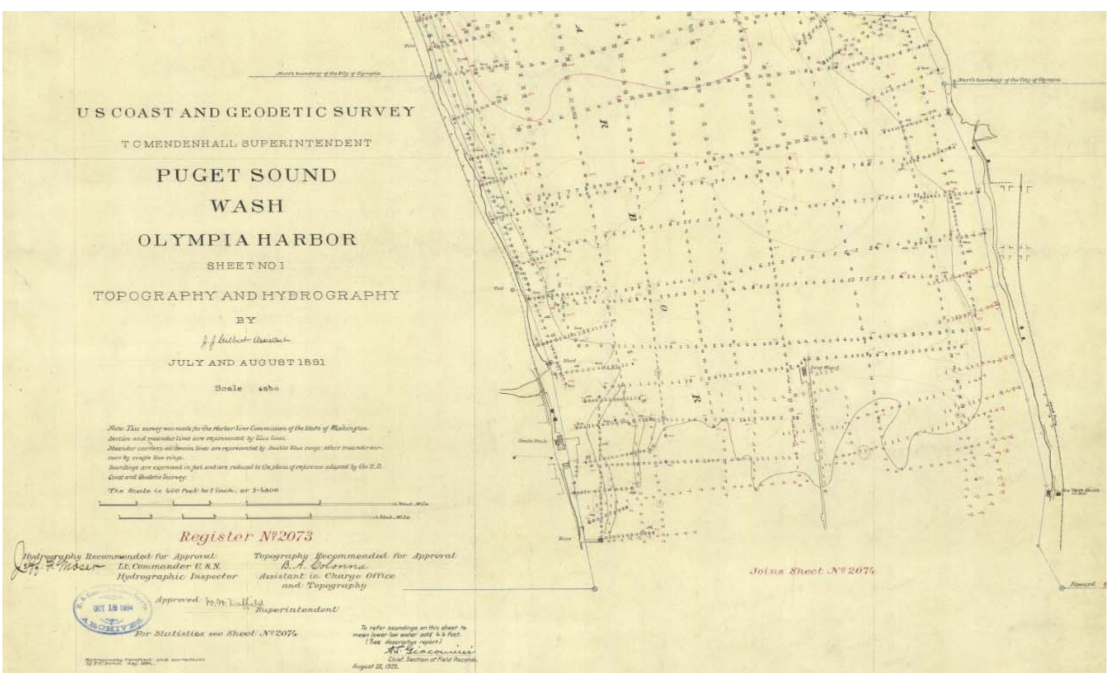
> "In comparing the surveys of the ocean shore lines of Nantucket Island, we have been obliged to limit the inquiry to an examination of the shore line as defined by the crest of the high-water line, without considering any shift in the submerged portion of the coast because of the insufficiency of the data afforded by the earlier hydrographic surveys… The island of Nantucket is fast becoming of great importance as a summer resort, a statement fully warranted by the increasing number of hotels and cottages built there each year. The examination of the stability of its shores thus becomes of prime importance to this summer population as well as to the inhabitants engaged in its shore fisheries. The absence of the knowledge which is brought out by just such a comparison as this, permitted the location, some years since, of a line of railroad and many valuable buildings upon a part of the shore where the changes are so great that in a few years more the ground on which they stand will have been washed into the sea and the capital involved lost beyond recovery".[19]

[18] Mendenhall, 1892—Part II, Prefatory Note, p. III.
[19] Marindin, 1893, p. 243



Detail from T-1785 Changes since 1846 in Muskegat Island and Nantucket Bay, 1887

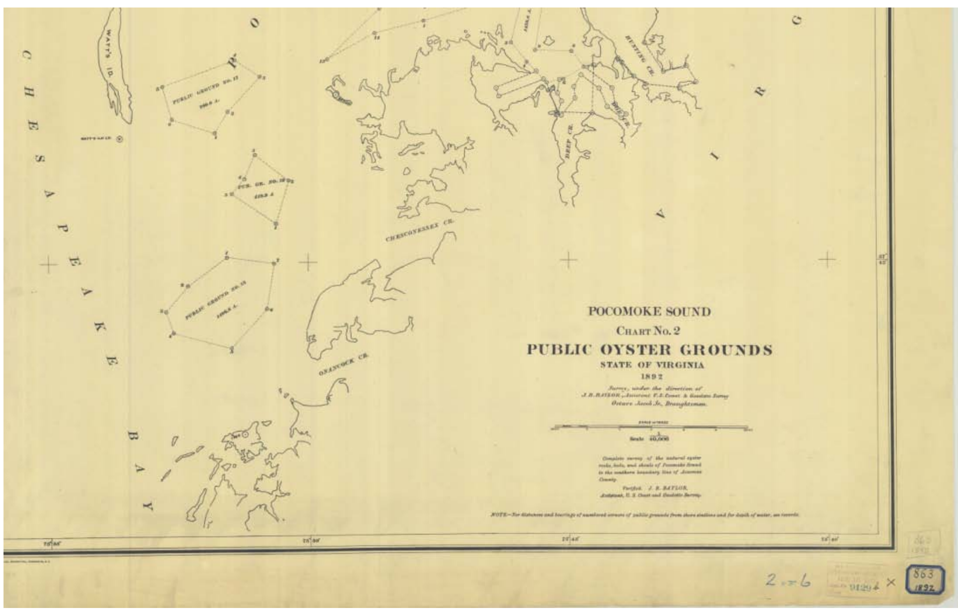
The Survey also initiated large re-surveys of important harbors that had not been examined closely since the Civil War, particularly Boston Harbor. On the west coast, the great increase in both populations and maritime commerce made charts created only a decade earlier obsolete. Many re-surveys were commissioned by harbor authorities and allied agencies.



Detail of H2073 (1891) Survey of Olympia Harbor, Washington Territory

The Survey also continued and expanded its research on the distribution and ecology of oyster beds and grounds. Francis Winslow withdrew from Survey work, as his oyster research was based on his assignment to the Survey as a Navy officer. When the Navy attempted to re-assign him to other navy duties, he quit his commission, which also severed his connection to the Survey. He then continued oyster research, and also attempts at commercial oyster management and cultivation, in Pamlico Sound and other areas of the North Carolina coast.

Other Survey personnel stepped in to continue Winslow's research path. The state of Virginia commissioned the Survey to set up a geodetic schema for mapping the public oyster beds of that state's water. And James C. Drake succeeded Winslow in oyster research in the Survey, publishing in 1890 his report on the sounds and estuaries of Georgia with reference to oyster culture.[20]



Detail from Public Oyster Beds of Virginia, No 2, Pokemoke Sound
Directed by J.B. Baylor of the Survey

Back to Alaska

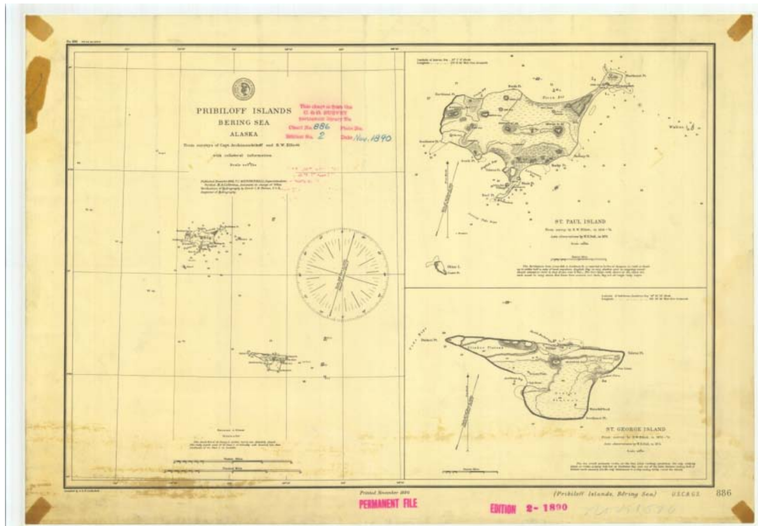
The Survey had been "present at the creation" of Alaska since 1867. But for the first several decades, work in Alaska and its extensive seas had been episodic, and limited to surveys of specific harbors, islands, passages, and other critical features of navigation. Many of the sailing direction scaled charts the Survey produced were derived primarily

[20] Drake, 1890, pp. 179-209.

from Russian and British sources. In the 1880s, this began to change. In 1884 the Survey launched the steamer *Carlile Patterson*, which had been designed primarily by the late Captain and Superintendent Patterson himself, for service in the relatively placid waters of the long inside passages between the rest of the United States and the Territory of Alaska.

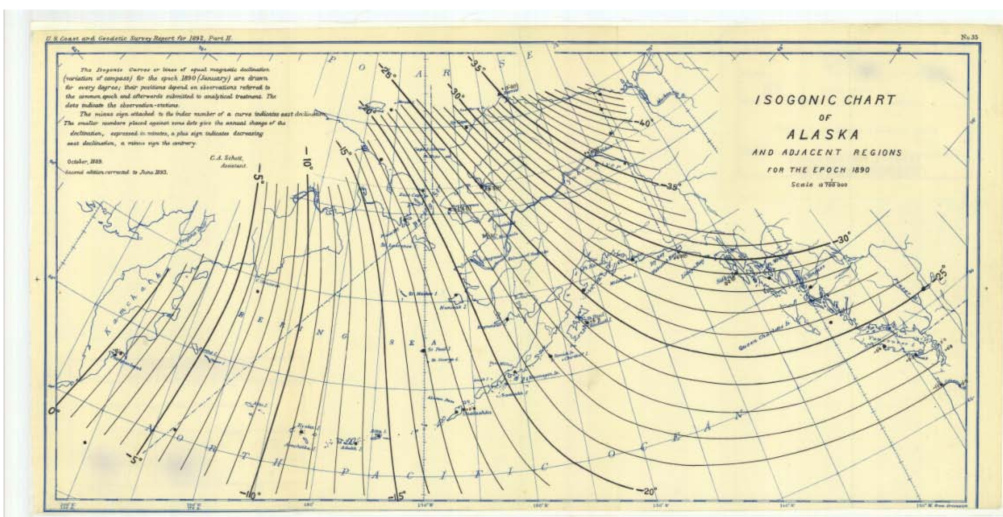
The steamer Patterson about 1910, in British Columbia
Photograph by future Survey Director Leo Colbert

The duties of the Patterson expanded by the end of the decade, driven by two major developments. The first was the continuing deterioration of the populations of fur seals on the Pribilof Islands, along with declining stocks of other marine mammals as well as fisheries in Alaskan waters. In response, American and British Navy vessels and U.S. Revenue Service cutters cruised the waters of the Bering Sea and approaches to it in management of the seal fishery. Mendenhall was appointed the American delegate to a joint U.S.-Great Britain committee to investigate the fur seals' situation, and in 1891 he sailed to the Bering Sea, taking time to make gravity observations with his half-second pendulum instrument, to be described later.



The 2nd edition (1890) of the 1875 charts of the major Pribiloff Islands
Based on Russian charts and the surveys of William Dall and Henry Elliott

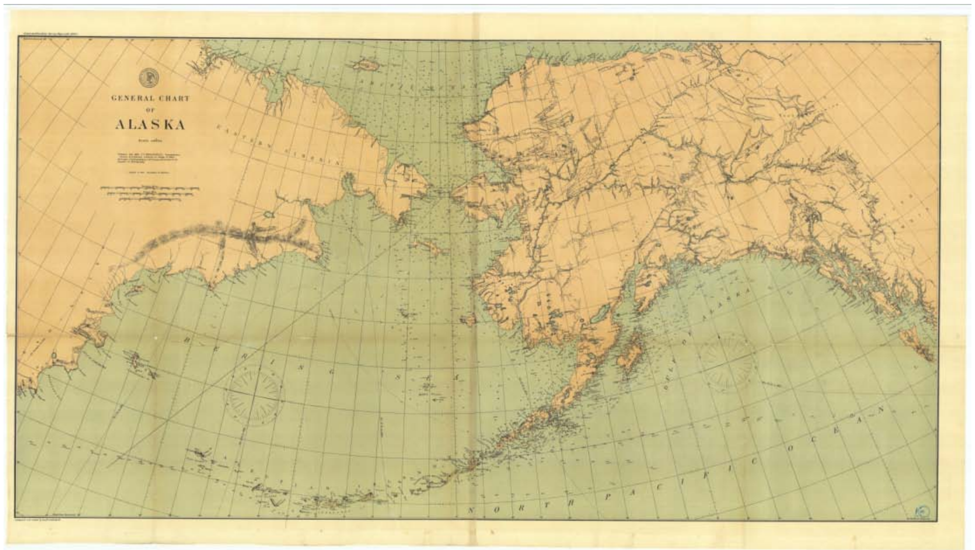
The other major development was the continuing and expanding phenomena of gold discoveries in British Columbia, and later Alaska and the Yukon Territory. This made previously small and obscure ports and harbors busy and crowded, and triggered large numbers of vessels and thousands of men to attempt travel to places never before used as ports by ocean-going steamships. The Survey was now tasked with an expanded workload of survey work over a huge area of land and water.



Magnetic Isogonic Chart for the Epoch of 1890 published in 1892.
The areas covered represent the major arena of Survey work

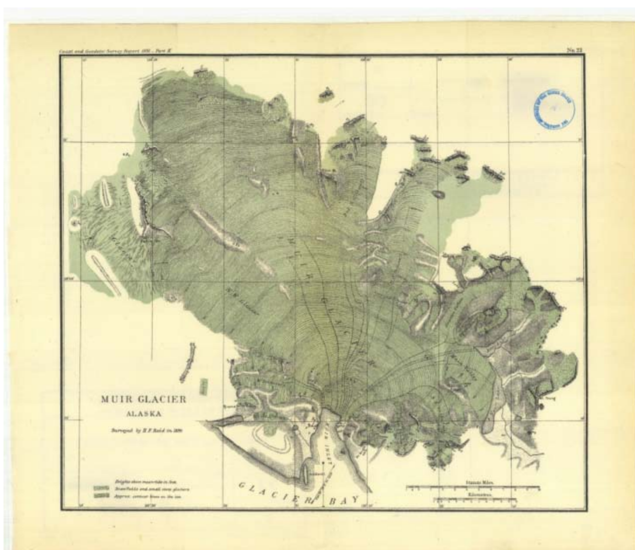
As always, new Survey work would result in new Survey charts. For some reason, never fully explained as such in the annual reports, Alaska and its adjoining area and seas, of all the American lands and waters, became the set upon which the Survey painted with color. Many Alaskan charts (although certainly not all) featured chromo-lithographic color as had not been seen in Coast Survey charts since the Civil War.

Eventually this expanded use of color would be used universally in Survey cartography, but it began in Alaska.



General Chart of Alaska, Sketch 3, 1890 Note that this chart and the previous isogonic chart use the same map projection

The use of color lithography extended to Alaskan-related maps and subjects on all scales, and even extended to color publishing in the annual reports.

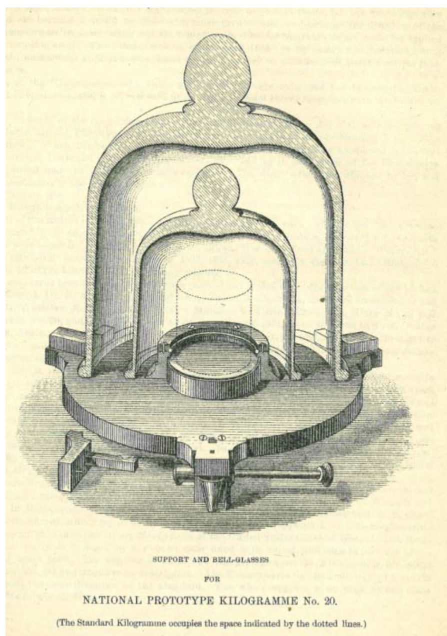


Muir Glacier Figure No. 22, Annual Report for 1891

The final major episode of Alaskan work under Mendenhall was the joint British/Canadian/American survey of the border between southeast Alaska and Canada, in which Mendenhall was directly involved. That will be further described in the section of Survey topography.

Geodetic Progress joins Metrology

Geodesy is inherently international in scope, and cooperative in nature, as all geodesists generally gain more by sharing data than by withholding it. Under Mendenhall there was the continued extension of the positioning related to the Great Arc of the 39th Parallel, lines of leveling of precision, re-determination of boundaries, etc. But the overall theme of Mendenhall's tenure was the standardization and internationalization of Survey geodetic work. Early in Mendenhall's term in 1889, George Davidson went to Paris—at his own expense, given the difficulties of Survey budgeting—as the American representative to the Ninth Conference of the International Geodetic Association. Various international research initiatives developed from Davidson's participation, including a variety of research projects in Hawai'i, described later. As a part of the collaboration, Davidson and future Superintendent Otto Tittmann played roles in transporting back to the United States various official metrological standards, including the metre bar and the standard kilogramme.[21]



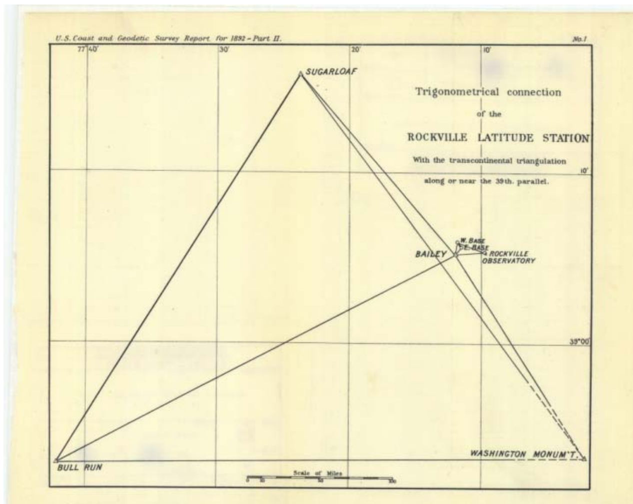
Support and Bell Glasses for the National Prototype Kilogramme
(dotted lines represent the kilogramme) No. 68, 1890

The American standards for the metre and the kilogramme brought back from Europe were taken in their sealed packing cases for a ceremonial revealing at the White House before the president and several dozen Senators and Congressmen then serving on Congressional committees related to Weights and measures, and also Judges and other leaders of society. Significantly, the observers included Julius Hilgard, the disgraced Superintendent who resigned from the Survey in 1885. Hilgard had been the first

[21] Davidson, 1890, App. 17 and Tittmann, 1890, App.18.

American delegate to the European enterprise that had resulted in the Conférence Générale des Poids et Measures (General Conference on Weights and Measures) which had defined the fundamental standards of the metric system. Hilgard had fallen under Cleveland, but President Harrison now occupied the White House, so Hilgard was welcomed back to formal Washington society, if only for the moment.

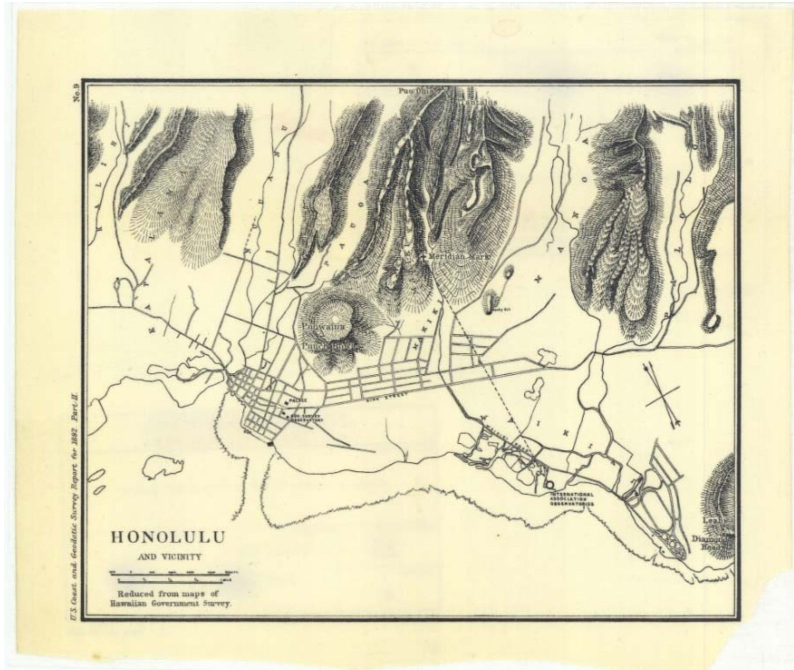
As part of American cooperation in international geodesy, the Survey accelerated astronomical latitude observations at its observatory site outside Rockville, Maryland. This was part of a set of observatories spaced around the world to determine and characterize the Chandler movements, the small wobblings of the Earth's axis. The Rockville observatory site was then trigonometrically connected to the great Arc of the 39th Parallel Triangulation Network by means of a small baseline and a near-equilateral triangle utilizing the Washington Monument.



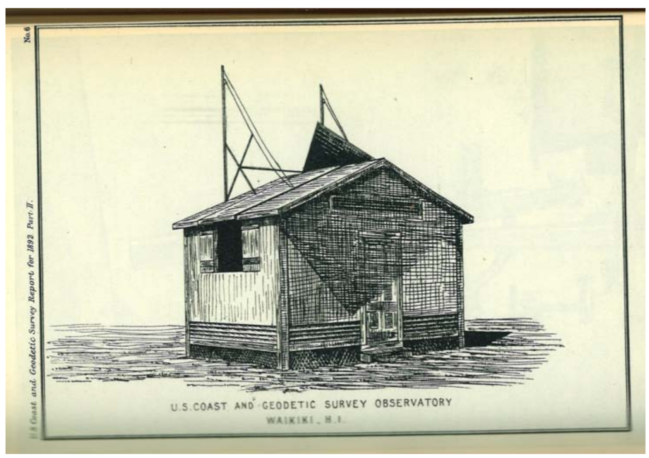
Trigonometric Connection to the Rockville Latitude Station No. 1, 1892

Collaboration with the International Geodetic Association also greatly expanded the scope of Survey research in Hawai'i. The context was recalled by the formidably named Assistant Erasmus Darwin Preston: "Some latitude observations made in Germany at Berlin and Potsdam, and at Prague in Bohemia, showed a progressive yearly change [in latitude] in the results. As the motion was in the same direction for all three places, it became desirable to make a further study of the movement by observing at stations differing greatly in longitude… therefore to bring out the law of change most advantageously the International Geodetic Association took the matter up and proposed to send an observer to the Hawaiian Islands…This led to my assignment by the Superintendent of the Coast and Geodetic Survey, with instructions for some additional gravity, latitude, and magnetic observations during my stay in the islands."[22]

[22] Preston, 1891, App. 13, p. 479

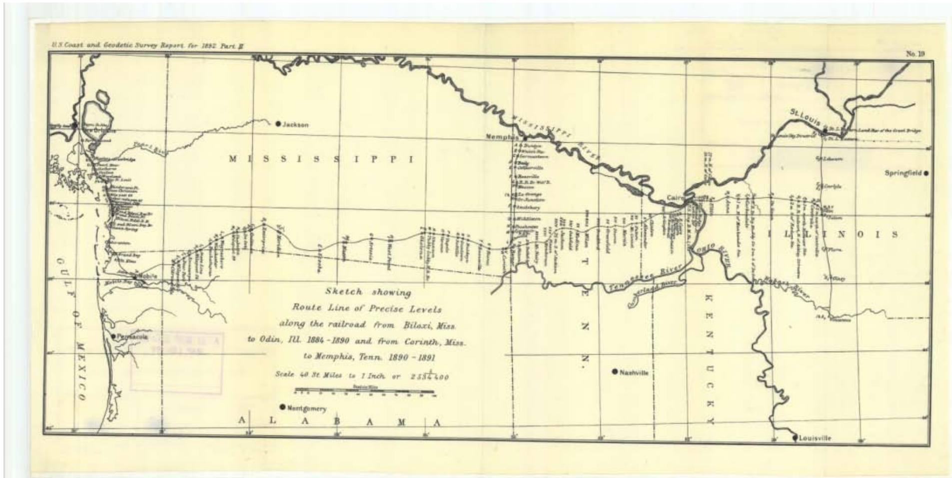


Honolulu and Vicinity, showing several of the observatories
associated with Preston's research. No. 9, 1892



The Coast and Geodetic Survey Astronomical Observatory at Waikiki, outside Honolulu
No 6, 1892

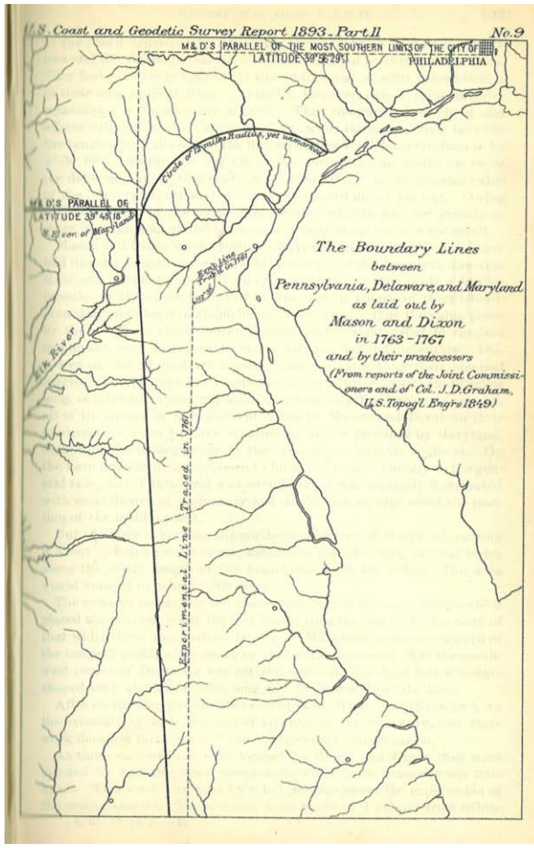
Back on North America, Survey geodetic work progressed in interesting ways. Survey parties using spirit levels of precision worked through much of the upland south, along new railroad lines established for upland logging and other transport operations.



Routes of Precise Leveling along Railroad Routes
No 19, 1892

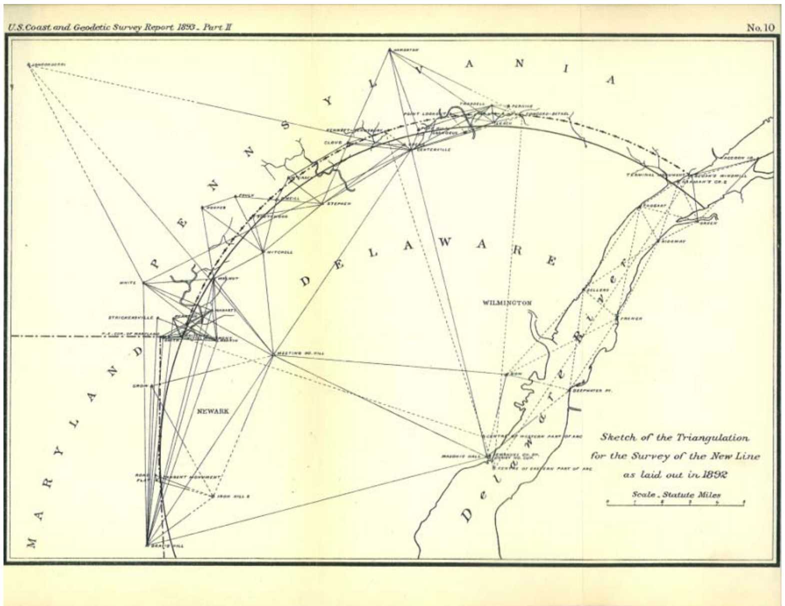
George Davidson and Charles A. Schott, among many other Survey scientists, had already done much research on historic nautical charts and other sources of maritime data both for historical research and for the aid of contemporary charting. In 1890, the Survey received an unusual task that extended their historical research to a legendary terrestrial data set. The states of Delaware, Maryland, and Pennsylvania required a re-survey of their contiguous boundaries, which are a set of lines, which are erroneously summarized as “the Mason-Dixon Line”. In order to complete the assignment, Assistant W. C. Hodgkins compiled a historical account of all European settlements and colonial boundaries in the area going back to1631.[23]

[23] Hodgkins, 1893, App. 8, pp. 177-222.



The Boundary Lines between Pennsylvania, Delaware, and Maryland
As laid out by Mason and Dixon in 1763-1767 and by their predecessors
No. 9, 1893

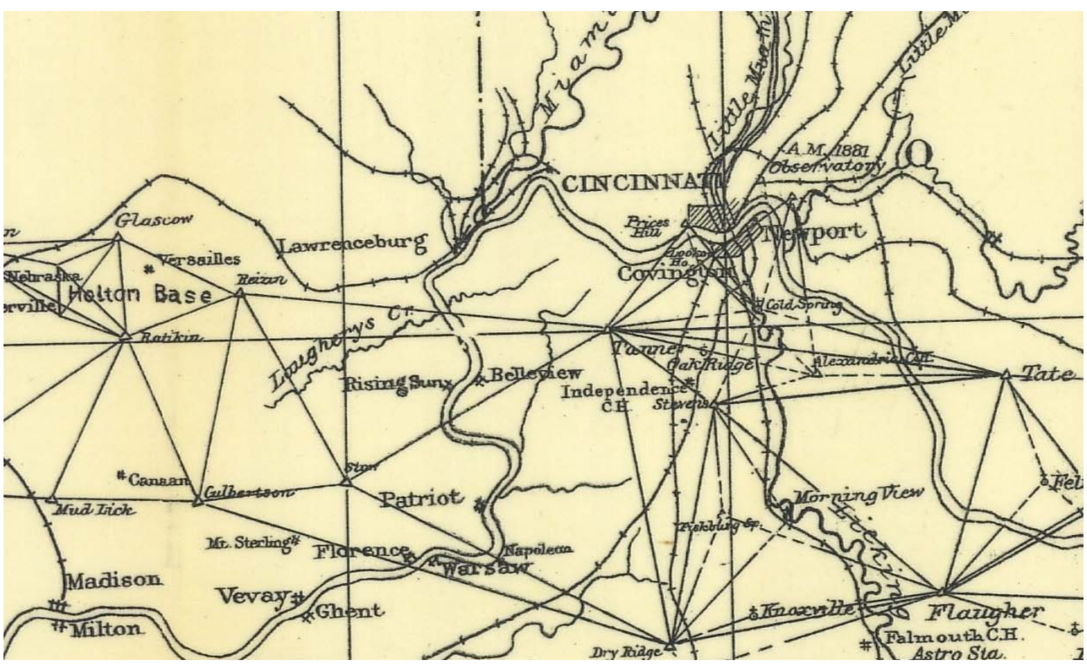
Based on the research, and the legal written descriptions of the boundary lines finally agreed to by the three states, the Survey precisely surveyed the boundary lines, and also the arc of a circle 12 (old English) miles in radius, a boundary feature unique in the United States, and possibly elsewhere.



Sketch of the Triangulation for the Survey of the New Line
No 10, 1893

The Holton Baseline

The final major geodetic project of the Survey under Mendenhall was the establishment of a unique baseline outside Holton, Indiana. It was near this place that, in 1891, the two long arcs of the Great Arc of the 39th Parallel Triangulation Network met, having marched between the Atlantic and Pacific Oceans since the beginning in 1871.



The location of the Holton Baseline west of Cincinnati, Ohio
Sketch 9, 1892

Mendenhall was both an educator and a maker of standards, and these functions converged with the project of the Holton Baseline. The major Survey personnel brought in for the project included Otto Tittmann, a major figure in the Office of Weights and measures, and later Superintendent of the Survey; John Hayford, later a major geodesist and developer of the Hayford Reference Ellipsoid, and R.S. Woodward, later to become the director of the Carnegie Institution of Washington. These were not the only principals on the project. Survey reports are often silent or cursory on the subject of the non-scientific but indispensable members of the party. One of these, who worked on the Holton Baseline, was a laboer named Jasper S. Bilby. As the geodesist William Burger noted, in his memoir of Hayford:

> "At Holton Base, Mr. Hayford formed an acquaintance with one of the men of the base party, and between them began a friendship which was destined not only to affect later his reputation as head of the Division of Geodesy in the U.S. Coast and Geodetic Survey, but in great measure to affect the geodesy of the United States and of the entire world. This acquaintance with Jasper S. Bilby lasted until the death of Mr. Hayford in 1925. When Mr. Hayford went to work on the United States-Mexican Boundary, Mr. Bilby was employed as general helper in his party and he has served continuously to date with the Coast and Geodetic Survey, with rare exceptions omitted, engaged for the most part in the Geodetic Division. Since about 1900 all of the major reconnaissance and signal-building has been in his charge and it was under Mr. Hayford's régime that special recognition was given him by conferring upon him the official title of Signalman, the first to be thus honored. In speed and economy of operation his work has had a distinct bearing upon the phenomenal success attained by the Coast and Geodetic Survey in triangulation and base work. He is the designer of the Bilby Steel Tower now being used with great success. Recently he again received official recognition by being given the title of Chief Signalman, this position having been especially created for him. The writer has had the pleasure of working with Mr. Bilby on many occasions, and believes that as an expert on reconnaissance and signal-building Mr. Bilby stands unrivaled in the world."[24]

The greatest source of error difficult to control or compensate for, in any baseline, is the expansion and contraction of the baseline instruments with temperature. Since the Holton Baseline was to be the geodetic joint between the Pacific and Atlantic baselines, it would be best if it was highly accurate. Mendenhall directed this baseline to be a test of different systems of baselines measurement compared to each other. "Soon after joining the U.S. Coast and Geodetic Survey in July, 1890, I was requested by Dr. Mendenhall, Superintendent, to devise means of testing in the most thorough way practicable the

[24] Burger, 1935, pp. 169-170.

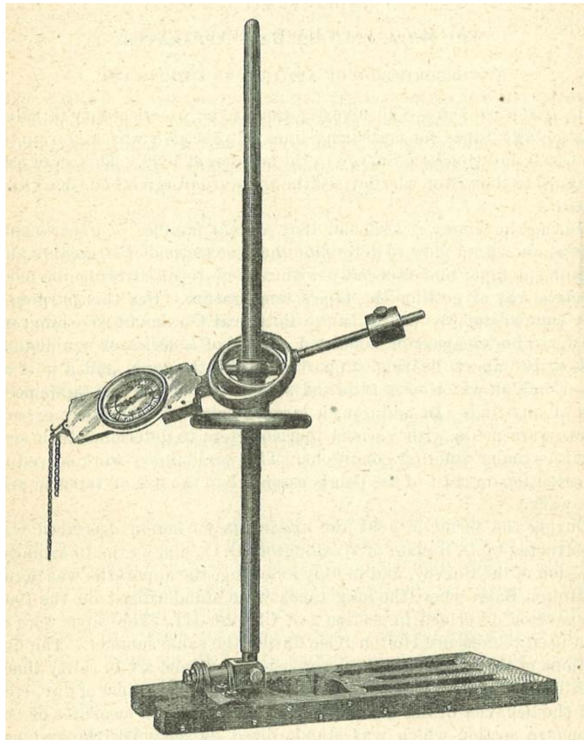
efficiency of the various forms of base apparatus used by the Survey, and especially the efficiency of long steel tapes or wires. Accordingly, considerable study was given to this subject during the autumn of 1890 and the winter of 1890—'91, and the plans and the specifications for the iced-bar apparatus considered in this paper were matured and approved early in the spring of 1891."[25]

The point of the iced-bar apparatus was to keep the baseline measuring bars as close as possible to the constant temperature of the freezing/melting point of water, to minimize differential contraction or expansion of the bars. However, the measurements of the iced-bar apparatus themselves had to be compared to non-iced-bar methods. The next set of comparative measurements involved different kinds of steel tape and steel wire, which had to be compensated for temperature and also for the force pulling the wire or tape taut.

The Iced-Bar Apparatus on the Standard Kilometer part of the Holton Baseline
No 32 1892

The iced-bar method was found to be highly accurate, and also time-consuming and expensive. But it gave a standard to which to compare various methods of measuring distances with steel wire and tape.

[25] Woodward, 1892, p. 338



Steel Tape Stretching Apparatus
Annual Report for 1892

In the end, the steel tape was found capable of working for geodetic standards of accuracy. “”The metallic tape is not only capable of giving a result of great accuracy when in the hands of experts, but it is evidently the best device for rapid base measurement where no great precision is aimed at.”[26] From that point on, steel tapes became standard in Survey geodesy work where accuracy standards allowed their use.

The Gravity of Mendenhall

The arrival of Mendenhall in the Survey led to the departure of Charles Sanders Peirce, after over 30 years of employment (most of the time) in the Survey. As always, Peirce himself and his unusual behavior was one issue, although by no means the only one. But Peirce wanted to obtain the absolute gravitational force at a site, which was not only extremely difficult, but was quite time consuming and hence expensive.

Ever since the depredations of Chief Auditor Chenowith and the investigations of the Allison Commission, Peirce had been dangerously marginalized in the Survey. Peirce had offered to resign under Thorn, but Thorn refused to accept it—since Thorn was not a rival of Peirce. Mendenhall was. He had been doing gravity research with pendulums since teaching in Ohio in the 1870s, and he had swung pendulums in Japan. And Mendenhall had a concept for smaller, lighter half-second pendulums, in contrast to

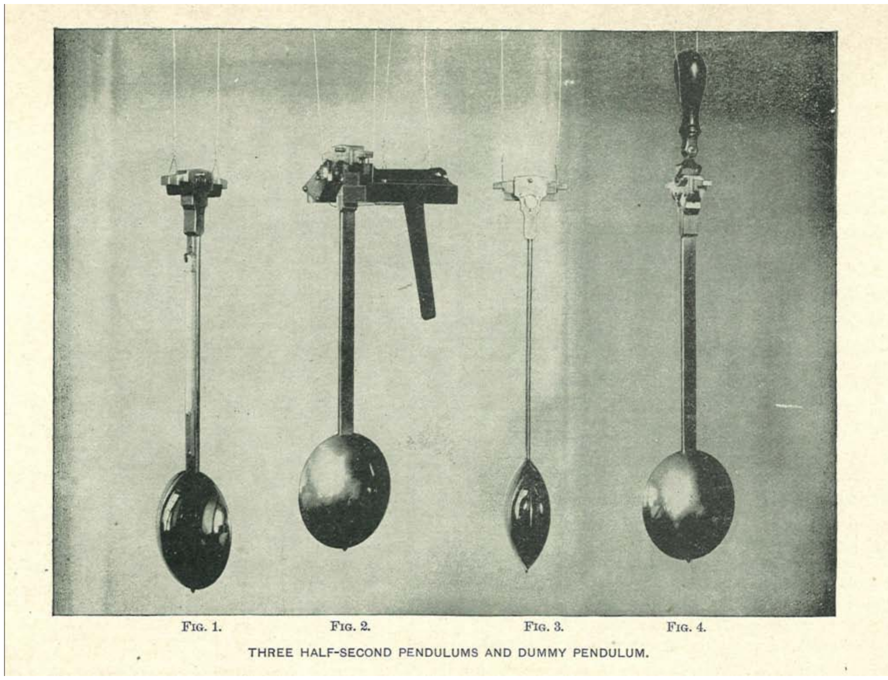
[26] Mendenhall, 1892, App. 8, Prefatory Note, p. 329.

Peirce's larger one-second pendulums. Peirce pointed out what he saw as insurmountable problems with Mendenhall's concept. Essentially, there wasn't room in the Survey for two rival gravity programs. Mendenhall forced Peirce to resign. Then Mendenhall's new concept was developed. His subsequent description of the program is revealing. Peirce is entirely unmentioned. Various Survey personnel are fully credited for their work, but Mendenhall himself is invisible in the account, even though this was Mendenhall's project entirely.

As Mendenhall described the history of gravity work in the Survey:

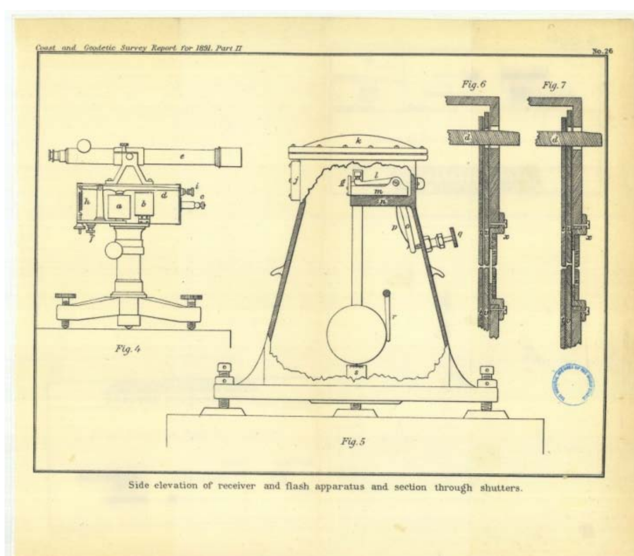
> "The active interest of the Survey in this subject began about 1873. The numerous and often extensive discrepancies between geodetic and astronomical positions indicated the importance of and necessity for the investigation, and the bearing of the results upon geological problems adds additional interest to it. Much valuable experimental work was done and a number of stations occupied, including several in the old world, from the beginning of the work up to 1890. Some form of pendulum whose period was approximately one second was used, together with a clock having a seconds pendulum; the method of coincidences and, for a few years, that of chronographic registration having been adopted in determining the period of the gravity pendulum. Reversible pendulums were generally made use of, but the measurements were in the main differential and not absolute. A serious difficulty in the way of continuing the investigation on this basis was its cost, when considered in connection with the number of stations occupied. The instrumental outfit of a party was large and not easy to transport; much was required in the way of preparation of a station, and thus a single determination involved the expenditure of so much time that it was extremely desirable to devise some means of more rapid working, especially if this could be done without material sacrifice of the accuracy which the nature of the problem demanded. It was agreed that a great reduction in the magnitude and complexity of the instrumental outfit of a party could be made by using a pendulum vibrating in a half second, and substituting a chronometer for the clock… It seemed altogether wise to make use of the method of coincidences in measuring the period of the pendulum, and also that some optical method of doing this was preferable to any other. It was determined that invariable non-reversible pendulums should be used, except at a limited number of base stations, where absolute values of the force of gravity should be obtained by the use of reversible pendulums or by some other method. In the elaboration of the plans for the work many valuable suggestions were secured from Mr. C.A. Schott, Mr. Edwin Smith, and Mr. E.D. Preston, assistants, the latter two having had large practical experience in gravity work; and in the designing and constructing the apparatus the services of Messrs. Smith and Preston, together with Mr. E.G. Fischer, chief mechanician, and Mr. G.R. Putnam, aid, U.S. Coast and Geodetic Survey, were invaluable in securing the

realization of the proposed improved devices, as well as the suggestion and invention of many of them".[27]



Three half-Second period Pendulums and a Dummy counterweight Pendulum
Nos 1-4, 1891

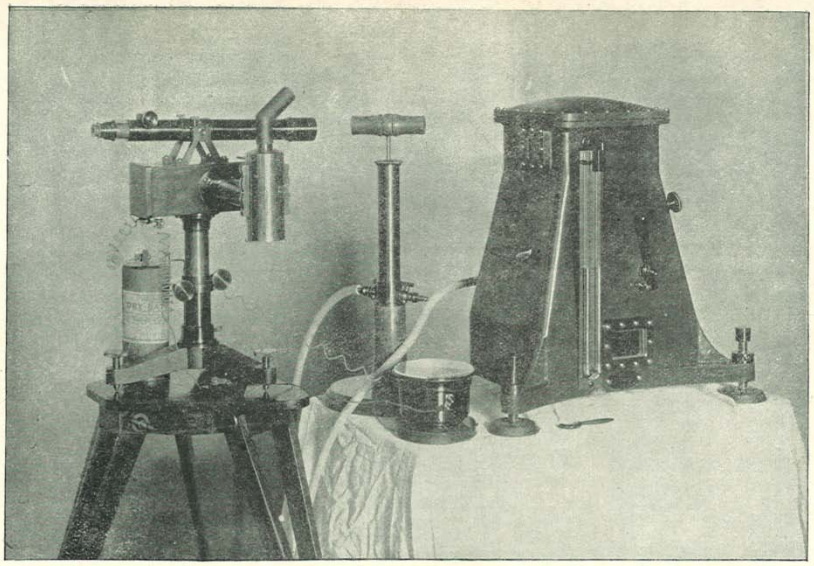
Mendenhall (and the others) developed the concept of swinging the pendulums in an enclosed case under partial vacuum, and also using an optical flash system to time the pendulums' swings.



[27] Mendenhall, 1891, Part II, pp. 503-504.

Side elevation of the system concept
No 26, 1891

The entire system, as built, was relatively compact and light-weight, especially compared to Peirce's apparatus.

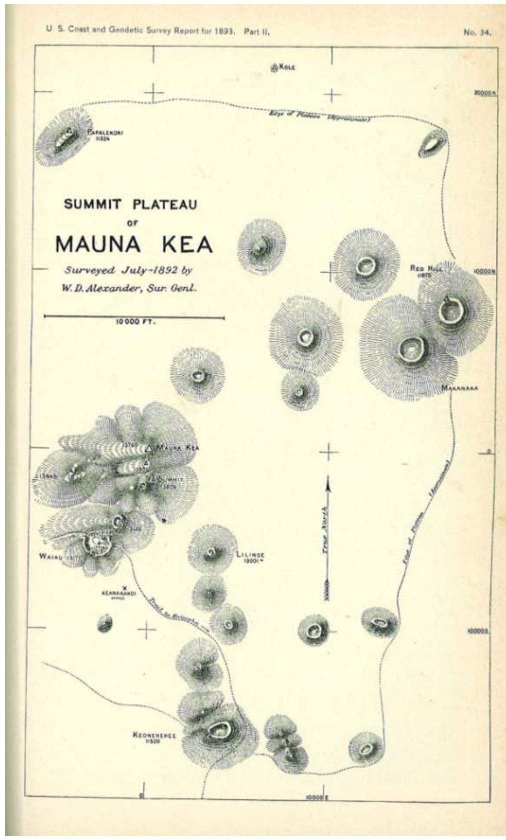


HALF-SECOND PENDULUMS.
Side view (right) of receiver, flash apparatus, etc.

The full pendulum system, with pendulum case, optical flash monitor, battery, and air pump for the partial vacuum. No 23, 1891

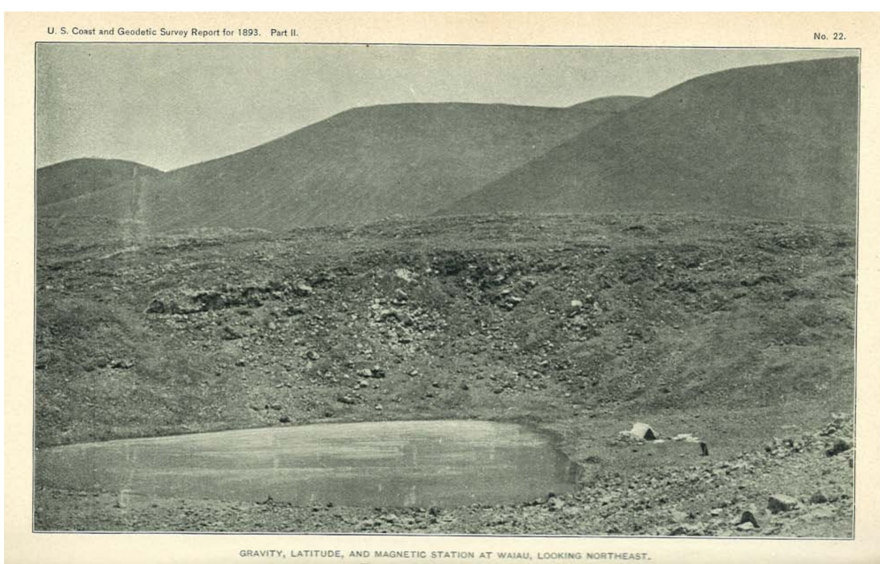
The Mendenhall pendulum system measured the relative value of gravitational force at a site to be compared to that of another site, but not the absolute gravitational force. Mendenhall compensated for this by taking his system to sites previously and laboriously occupied by Peirce's apparatus in order to at least partially calibrate his system. Then the Mendenhall pendulums traveled widely, taking advantage of their smaller size and rapid use. Mendenhall and his party made observations along the Pacific coast and Alaskan coast and islands when he went to the Bering Sea to investigate the fur seals, and also when he returned to Alaska in 1892 as the lead American delegate to organize the joint US-British survey of the Alaskan-Canadian boundary. Assistants Smith and Putnam swung the pendulums in various locations in the United States.

And Assistant Eramus Darwin Preston took a set to Hawai'I, where he conducted gravity research, in addition to the astronomical and magnetic work already discussed. His most extensive research was on the big island of Hawai'i.



The Summit Volcanic Plateau of Mauna Kea surveyed by W.D. Alexander of the Hawaiian Geodetic Survey and later the US Coast and Geodetic Survey No 34, 1893

Preston made numerous gravity observations in transects crossing from sea level up and over the volcanic summits of the big island and several others.



Station at Weiau looking northeast No 22, 1893

Preston documented his gravity stations by positioning them geodetically with theodolites and other instruments, and also took photographs of the stations in context. These photographs are now considered quite valuable to Hawaiian researchers studying changes in vegetation and landforms since Preston's expeditions.

Mauna Kea and Kaleiha as seen from a plantation-ranch where Preston's party camped
No 32, 1893

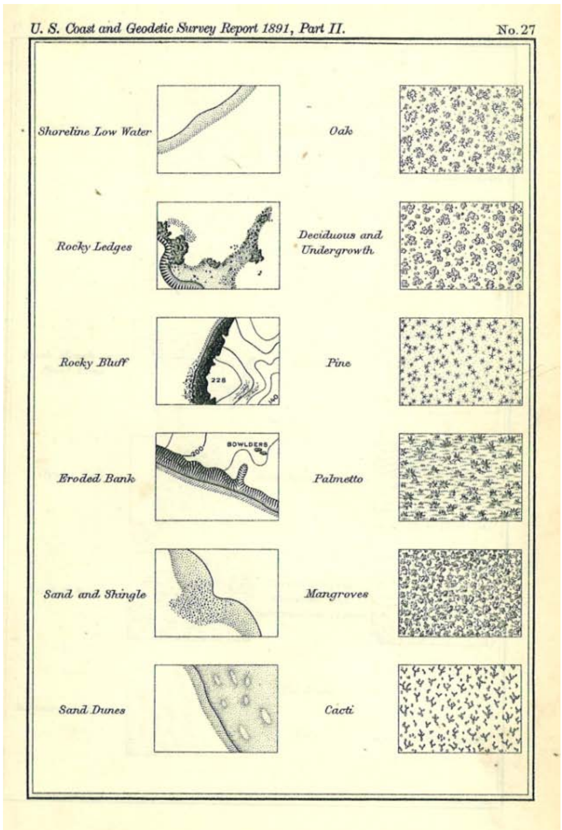
Mendenhall was only with the Survey about four years, but his pendulum system survived his exit; Mendenhall pendulums were used as long as the Survey continued to use any pendulums at all. Their fatal flaw—and also those of Peirce—was that the pendulums balanced and swung on a conceptual 'knife-edge' beam that was never as thin as the concept, and that inevitably introduced errors that skewed the measurements, precluding the kind of accuracies that Peirce in particular spent his life attempting to achieve.

Scaling and Mapping the Topographic Heights

Mendenhall was brilliant and enthusiastic and organized, but he was also rather small and delicate, and easily subject to ill health when under stress. He therefore never attempted any field work that couldn't be carried out from a beach or headland reached by a Survey vessel on his various travels as Superintendent. Nevertheless, the topographic work and research methods advanced strongly under his tenure, induced as Mendenhall could by the methods he was most familiar with as an educator and specialist in metrology and the naming of things.

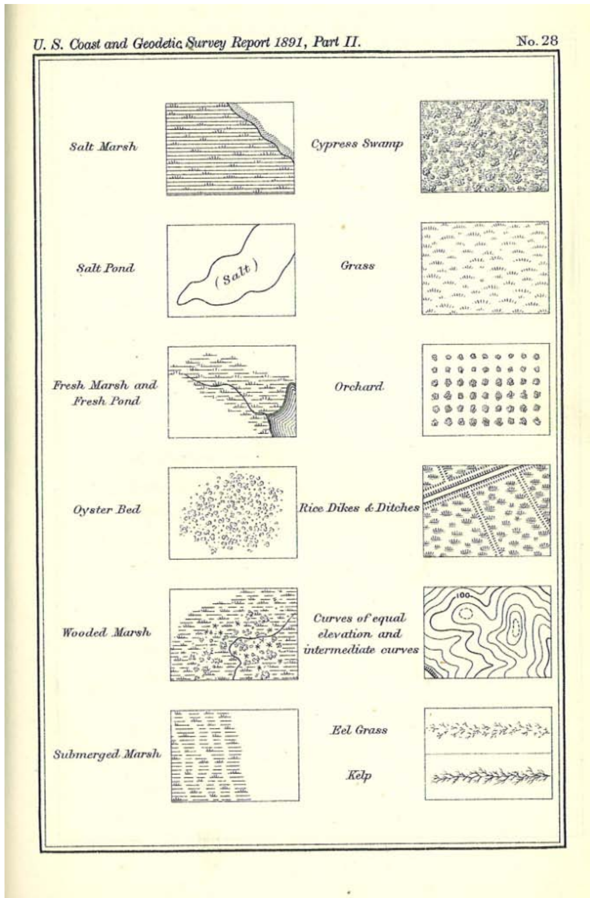
Early in his tenure, he took on the challenge that there was no consistent schema for naming geographic features on the many maps and publications of different government bureaus, even though correct naming could be, for example, in the case of nautical charts and navigation, a matter of life and death. He decided to remedy this. "A correspondence with the heads of Departments and chiefs of Bureaus especially concerned in the production of charts, maps, and other geographical publications was undertaken by the Superintendent of the Coast and Geodetic Survey, in which it was proposed to organize a Board consisting of representatives from such Departments and Bureaus, to which might be referred all questions arising in any of them relating to geographic names, the action of such a Board to be accepted as final, to the end that uniformity of nomenclature might be secured in all Government publications." The suggestion received favorable consideration in all quarters and resulted in the organization of the US Board on Geographic Names in April, 1890. [28]

In 1892, Mendenhall organized a conference of many of the most experienced topographers in the Survey—Henry Whiting, R.M. Bache, Augustus Rodgers, W.H. Dennis, Cleveland Rockwell, John W. Donn, C.T. Iardella, Herbert G. Ogden, D.B. Wainwright, W.C. Hodgkins, and J.A. Flemer—at Survey headquarters in Washington. They met daily from January 18 to March 7, 1892—with full pay, by the way—considering many topics of topographic surveying, accuracy standards, survey costs, etc., and also considering responses to circular letters submitted by many senior Survey scientists, draughtsmen, and cartographers and printers in the Survey. The resulting voluminous report was published in Appendix 16 of the 1892 annual report.[29]



Conventional Topographical Symbols, No 27, 1892

[28] US Board on Geographic Names, Prefatory Note, 1890, p. iii.
[29] Proceedings of the Topographical Conference held at Washington, DC January 18 to March 7, 1892.



Conventional Topographical Symbols, No 28, 1892

The Topographical Conference included J.A. Flemer, who was the Survey's specialist and first early adopter in the new discipline of photogrammetric topography, which used sets of stereo-pairs of photographs, with cameras aimed horizontally, and careful measurements and mathematical models, in order to determine three dimensional landscape forms and positions and elevations photogrammetrically. The technique originated with mapping bureaus in the European countries which shared the Alps, and was particularly useful in such areas of high relief, which were so difficult to map by plane table and spirit level. From there, the modified technique came to Canada. Flemer further modified the Canadian camera system to create the first American photogrammetric mapping system. He published several comprehensive appendices on the theory and methods of photogrammetry in annual reports.

PHOTOGRAPHIC INSTRUMENTS AND METHODS EMPLOYED FOR TOPOGRAPHIC SURVEYS IN THE DOMINION OF CANADA.

The phototopography of the Rocky Mountain region in the Northwest Territory of the Dominion of Canada proved a success, and several of the Dominion topographic and land surveyors (J. J. McArthur, W. S. Drewry, etc.), under the direction of the surveyor general, Capt. E. Deville, have acquired skill and valuable experience in this branch of surveying, as is well proven by Deville's topographic map of the Rocky Mountains along the Canadian Pacific Railroad, based on triangulation and phototopography, plotted on 1:20000 and published on 1:40000 scale, and which was on exhibition at the Columbian World's Fair.

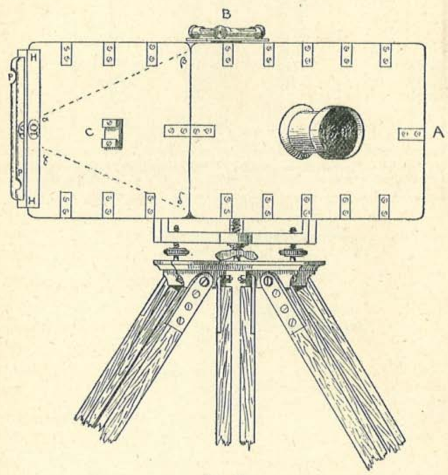


FIG. 16.

Under the direction of Dr. W. F. King, Alaskan boundary commissioner to Her Majesty, phototopography has been successfully employed for the topographic survey of southeastern Alaska, as far as this topographic reconnaissance has been executed under the Government of the Dominion of Canada.

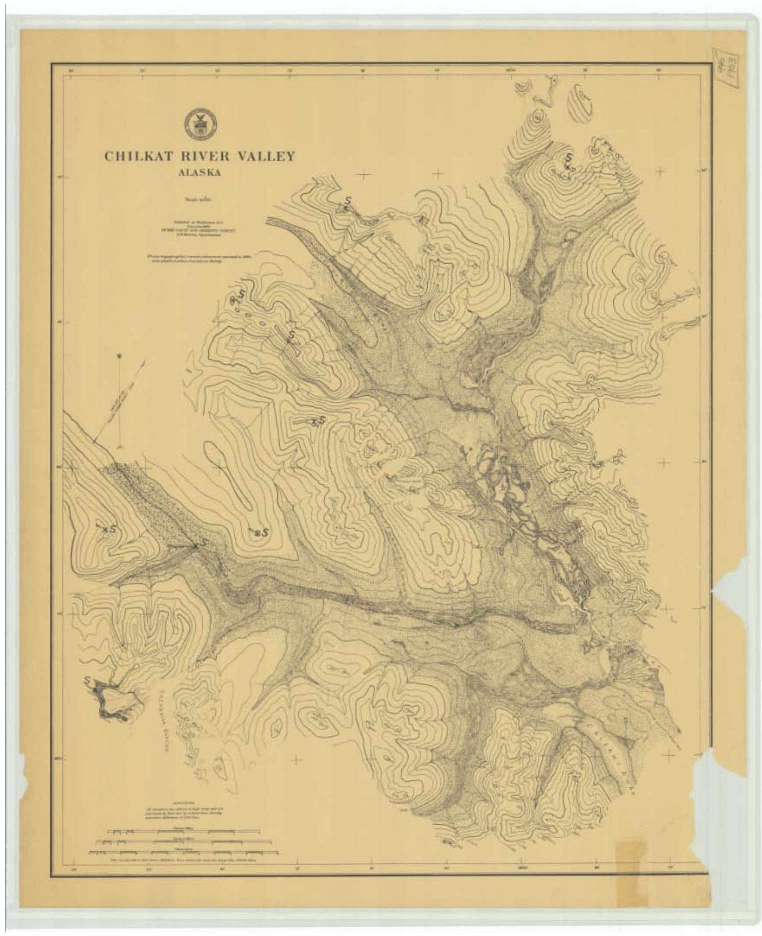
Canadian photogrammetric camera and context of its uses
No 16, 1893

It is interesting to note that the Coast Survey had used photography extensively since the late 1840s, as Superintendent Bache had then noted: "But above and before all other reasons, photography was to be introduced as a regular part of office detail, and great changes were necessarily consequent. I determined therefore to have a thorough revision of the whole system…"[30]. Nevertheless, almost half a century later, Flemer's appendix shows the very first cameras ever depicted in an annual report.

In 1892, the U.S. and British and Canadian governments decided to jointly determine an actual boundary line between Alaska and Canada along the south east "panhandle" portion of Alaska, which had been only vaguely indicated in the Russian documents when the U.S. bought Russian America in 1867. The topographic work was divided between the American parties, which worked from the Pacific coast up into the glacial valleys of southeast Alaska, and the British-Canadian parties which worked from the mountain heights down. This difficult work took many years, and the disputes over where to put the boundary line segments even longer. The first Survey map to be produced based on "photo-topographic reconnaissance' was published in 1903, based on surveying done in 1898. Ironically, the map is a portion of the Chilkat River Valley,

[30] Bache, 1860, Annual Report, Superintendent's Report, p. 19.

including Kohklux' village of Klukwan (here spelled Klookwan) where George Davidson had observed the solar eclipse in 1869, on the second Survey voyage to Alaska.



Chilkat River Valley, 1903

Mendenhall was, in some ways, above all else an educator. Despite the many problems and challenges the Survey faced, and despite its many enemies, Mendenhall managed to fund and execute a series of conferences that allowed virtually all the top scientists of the Survey to assemble in Washington for reasonably lengthy periods of time to address certain topics—and at full pay. There was the topographers' conference, several geodesists' conferences, and a gathering early in 1893 related to the preparation of exhibits for the Coast and Geodetic Survey's entry at the World's Columbian Exhibition in Chicago. The resulting staff photograph was only a partial view of the Survey, as it excluded all the Survey personnel other than Assistants. Nevertheless, it would be decades later, under the populist patrician E. Lester Jones, that the Survey ever attempted a mass photograph of its working staff.

George Davidson, Thomas C. Mendenhall, and Charles A. Schott cropped from the 1893 photograph of Mendenhall and the Survey's Assistants

"An Epoch in Metrology"

"The fiscal year 1890 has been marked by a steady and systematic development of the operations of the Survey in both field and office, and by advances so notable in the closely allied work of the Office of Weights and Measures as to constitute an epoch in metrology."[31]

Probably Mendenhall's signal achievement in the Survey, or at the least the achievement that he himself would have valued most highly, was the process by which the Coast and Geodetic Survey became situated more centrally in the organizations and mechanisms of international science and technology. He accomplished this by insistence on definitions and standards. These included the metric standards, and also the foundation and processes of the Board on Geographic Names.

His finale, perhaps, was the development and approval of the definitions and standards of the fundamental units of electricity. He did this by the International Congress of Electricians, which met in August, 1893 in Chicago in conjunction with the World's Columbian Exposition. There were unexpectedly large delegations, and many famous scientists among them, chiefly Dr. H. von Helmholtz, who served as honorary

[31] Mendenhall, 1890, p.1

president of the gathering. According to Mendenhall's own account of the Congress and what transpired:

> "It is true that the science of electrical measurement had been thoroughly explored; excellent methods and instruments have been devised and constructed, and the most perfect system of units of measure ever conceived has been developed during the last quarter of a century. These units being continually in use among scientific men, had come to be recognized as in some degrees authoritative among those engaged in commercial applications of electricity. But in general no legal values were attached to these untis, and in reference to two or three of them scientific men were not yet in entire accord in their nomenclature and definition…
>
> "The results of these investigations, and the general progress of the science of electricity during the past decade, were such as to justify the belief that the time had now arrived when an international agreement could be reached upon definitive values of the units desirable and necessary in electrical measurement, as well as upon the names they should bear… As already stated, it is not the purpose of this article to discuss the conclusions reached by the Chamber of Delegates from a scientific standpoint, but it will be desirable to name the units selected, and explain in a general way their technical significance. In the order of their adoption by the Chamber they are: the ohm, the ampere, the volt, the coulomb, the farad, the joule, the watt, the henry".[32]

Characteristically, Mendenhall left out of the account the fact that he had written the basic definitions, which were then approved by the small, elite Chamber of Delegates, and then approved by the full Congress. After the Congress and the Exposition, Dr. von Helmholtz made a triumphant tour across the United States, culminating in Washington, DC, where Mendenhall was his host in the city. Ironically, it was Von Helmholtz' finale as well, as he fell aboard ship on his return to Europe, and died of his injuries.

[32] Mendenhall, 1894, p. 606.

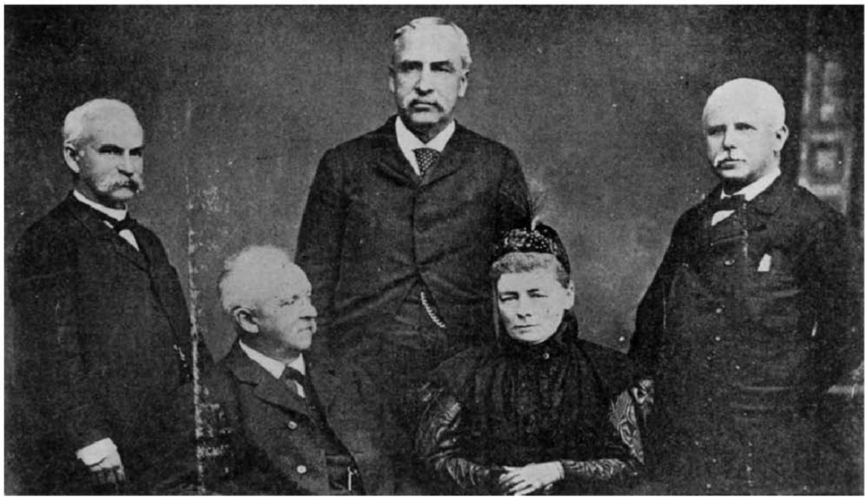


Figure 3. Helmholtz in Washington, DC, 1893. Hermann and Anna von Helmholtz are seated in the centre. Standing on the left is the German physiologist Hugo Kronecker; in the centre is Henry Villard; and on the right is Thomas Corwin Mendenhall. Source: *Popular Science Monthly*, 85 (1914), 517.

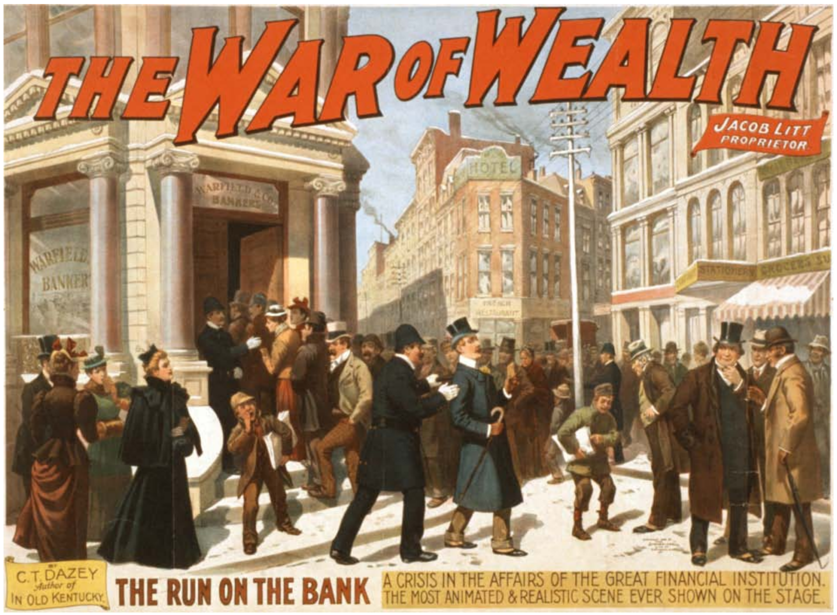
Dr. von Helmholtz (seated, left) and Mendenhall (standing, right). Standing in the middle is Henry Villard, the financier, who, interestingly enough, was the first cousin of Julius Hilgard, the former Superintendent

The convergence of all these activities was the publication of a set of Bulletins of the Coast and Geodetic Survey in Mendenhall's favored octavo format. These included: Bulletin No. 26 Fundamental Standards of Length and Mass; Bulletin No. 29 The Methods and Results of the U.S. Coast and Geodetic Survey, as illustrated at the World's Columbian Exposition, which itself had 14 different sub-divisions covering the full array of Survey work and its many publications, including a unique physical model of the United States and Alaska "as if they were cut out from sphere about 42 feet in diameter"[33]; Bulletin No 30 Units of Electrical Measure; and Bulletin No 31 Legal Units of Electrical Measure in the United States.

The End of the Epoch

The year 1893 encompassed both the World's Columbian Exposition and the Panic of 1893. The Philadelphia and Reading Railroad went bankrupt in February, only 10 days before Grover Cleveland was inaugurated to an unprecedented second separate term as president. A cascade of bank and railroad failures soon led to the biggest depression the country had ever faced. That, and the increased Democratic majority in Congress, spelled trouble for the Survey and Mendenhall.

[33] Bulletin No. 29, Model of United States and Alaska, p. 95.



"The Run on the Bank" from *The War of Wealth* by Charles Turner Dazy (1895)

The Survey's congressional foes used the familiar combination of attempts to cut Survey funding, and attempts to once again dismantle the Survey into the Navy Hydrographic Office. But the final straw came through actions from the Executive branch. Cleveland appointed James G. Carlisle as Secretary of the Treasury, who appointed his son Logan s chief of the division within Treasury that appointed people to positions. They wanted patronage positions from the top to the bottom of the Survey, and they used tactics that were almost impossible for the placid and mild-mannered Mendenhall to successfully oppose. On top of all this, Mendenhall's health began to deteriorate, as it had done in certain critical periods of his life previously.

Whatever else, Mendenhall had other options. In April, 1894, he quietly took a position to become the president of the Worcester Polytechnic Institute in Massachusetts, although he would stay as head of the Survey long enough to complete various obligations. In June, he went to President Cleveland in the White House with a letter of resignation. Cleveland asked him not to resign and say nothing about the matter. Mendenhall agrees, but rumors flew about Washington that he had resigned. This became front page news in Washington. The Washington Times addressed the rumors that he had written the letter of resignation: "It was stated further that he assigns as a reason for resigning that the force in his bureau, which is under the Treasury Department, has been greatly changed, and inferior men selected in the place of men of experience who had formerly held the places. At this point, Mendenhall failed. He was accosted at his house at a late hour. When asked about the rumors of his resignation, "after some urging, he said this: 'I will say this. For all I know, I am still in charge of the Coast Survey Department, and for all I know I will be for a long time to come. I am ignorant as to where this report originated, but can say frankly that it never came from me."[34] Unfortunately, apparently the only people who believed this account were the senior staff of the Survey. This limited their abilities to organize some defense against the coming onslaught.

In late June, 1894, Mendenhall left Washington, nominally for a three week vacation in Europe. His plan for the Survey was for Assistant Colonna and Henry Whiting, the senior topographer and last Survey scientist who had worked under Hassler, to jointly run the Survey in his absence. The plan was hopeless. "It is reported that Professor Mendenhall, of the Coast and Geodetic Survey, has accepted the presidency of Worcester Polytechnic Institute, but the story cannot be confirmed". [35] That same day, Henry Whiting arrived in Washington from the field, to be the acting Superintendent. He found a note waiting from Secretary Carlisle, that Mendenhall's action "was illegal and of no effect".[36] Whiting used connections to appeal to President Cleveland. Cleveland told him that any acting Superintendent should have his appointment confirmed by the Senate, just as the actual Superintendent was confirmed. On July 13, the staff of the Survey learned that treasury tax officer named William H. Pugh had been appointed Acting Superintendent of the Survey. The Survey's nadir had begun.

Mendenhall's later life

In the first half of the Survey's existence, superintendent's served until they died, and they were so busy while alive that their only memoirs were represented by the Survey's achievements under their direction. With Hilgard's disgrace and resignation, another era began, in which Superintendents might survive the Survey. Thorn survived many decades, and wrote a memoir, in effect, in preparation for the Survey's centennial. Mendenhall had virtually an entire new career after the Survey. He was director of the Worcester Polytechnic Institute, and eventually returned to Ohio and Ohio State University. There he assembled a 900 page autobiographical manuscript.[37] He also edited the multi-volume project of the history of Ohio State University.[38] And in 1922, three years before his death in 1925, he published a reminiscence of events back in his young Quaker abolitionist days as his community celebrated the end of slavery and the surrender of General Lee. He had been, all his life, a man who accentuated the positive. That accounted in no small way for his many accomplishment sin the Survey, and also his abrupt and sad departure.

[34] "Is Mendenhall In or Out" Washington Times, page 1, June 23, 1894.
[35] Washington Times, July 8, 1894, p. 8
[36] As cited by manning, 1988, pp. 120-121.
[37] Mendenhall, Autobiographical Notes, in the Mendenhall Papers, Center for the History of Physics, College Park, MD.
[38] Mendenhall (ed), 1920.

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